Action:
- distr to team
- initial ORD review
- disc of Cat[illegible].

To Be Included in Prefinal Design 7/14/2004

5.8

TECHNICAL MEMORANDUM

To: Kevin Parrett, Oregon Department of Environmental Quality, Northwest Region (NWR), Portland, Oregon

From: Chad Nancarrow, Ecology & Environment, Inc., Seattle, Washington

Subject: Evapotranspiration Cover Performance Expectations Technical Memorandum, McCormick & Baxter Superfund Site, Portland, Oregon, Task Order No. 71-03-12-01, E & E Project No. 0016688.OY12.14.03

Date: July 8, 2004

1.0 INTRODUCTION

Ecology & Environment, Inc., (E & E) under contract with the Oregon Department of Environmental Quality (DEQ), has prepared this Technical Memorandum (memo) to support remedial design (RD) activities at the McCormick & Baxter Superfund Site (Site). This document has been prepared under DEQ Task Order No. 71-03-12-01, which concerns implementation of RD activities at the site in accordance with the remedy described in the *Record of Decision* (ROD; EPA/DEQ 1996), the March 1998 *ROD Amendment* (EPA/DEQ 1998), and the August 2002 *Explanation of Significant Difference* (ESD; EPA/DEQ 2002).

1.1 Objective

The objective of this memo is to:

- Present performance expectations of an evapotranspiration (ET) cover for capping the upland portion of the Site; and
- Provide a cursory evaluation of an ET cover as compared to a multi-layer, impermeable cover.

1.2 Background

For general Site background information (e.g., location, history, etc.), refer to documents posted on the *McCormick and Baxter Superfund Cleanup Site* website, located at the following address: http://www.deq.state.or.us/nwr/McCormic_and_Baxter/mccormick.htm

The remedial action objectives (RAOs) and selected remedies as presented in the ROD, ROD Amendment, and ESD for soil, groundwater, and sediment can also be found at the above referenced website.

1.3 Memo Organization

This memo will be presented in the following order:

- Section 2: Percolation Modeling Results;
- Section 3: Overview of ET Cover in Humid Environments;
- Section 4: Comparative Analysis of ET covers to Impermeable Covers;

- Section 5: References;
- Tables;
- Figures; and
- Appendices
  - Appendix A: Ecolotree Design Report
  - Appendix B: Cost Estimates
  - Appendix C: Schedules

1.4 Path Forward

It is anticipated that conclusions drawn from this memo will aid in decision making on whether an ET cover or an impermeable cover is most appropriate for capping the area within the barrier wall. Output from the percolation modeling (discussed in Section 2) will be used as input for groundwater modeling (currently underway) to evaluate the effects of various capping scenarios. Ultimately, the groundwater modeling results, in conjunction with a revised Conceptual Site Model (CSM) and NAPL Transport Update, will determine if installation of an impermeable cap is necessary in order to meet the Site's RAOs.

The draft groundwater modeling report is expected to be completed by mid-July 2004, and the draft CSM and NAPL Transport Update is scheduled to be completed in early August 2004. The decision to implement construction of an ET or impermeable cover is expected to be made by late August 2004.

2.0 PERCOLATION MODELING RESULTS

Ecolotree® from North Liberty, Iowa, was subcontracted by E & E to assist in the design and to perform infiltration modeling for an ET cover at the Site. The HYDRUS-1D model was used to evaluate infiltration through fourteen different ET cover options, including three grass-only designs, four hybrid poplar forest designs, four native deciduous forest designs, and three conifer forest designs.

Several parameters were input into the model including climatic conditions, soil properties (i.e., texture, depth), and plant properties [e.g., potential evapotranspiration (PET), crop coefficient (Kc)].

Daily precipitation data from 1992 to 2003 for the Portland International Airport was utilized for all model simulations. This data was obtained from the Western Regional Climatic Center, located in Reno, Nevada (WRCC 2004). The average annual precipitation during this time period was 38.3 inches, ranging from 29.5 inches in 1992 to 63.2 inches in 1996 (WRCC 2004). The Portland International Airport is located approximately 8 miles east of the McCormick and Baxter site. The City of Portland Bureau of Environmental Services (BES) Combined Sewer Overflow (CSO) program has been collecting rainfall data throughout the Portland, Oregon area for the past 25 years (Adderley 2004). The data collected is part of the HYDRA Rain Network (USGS 2004). The BES CSO program has created "virtual gages" for each quarter section of the city, simulating a rain gage at the center of each quarter section using the actual measured data and the reciprocal distance-squared method of interpolating between gages (Adderley 2004). The rain gage nearest to the McCormick and Baxter site is the WPCL Raingage (Station 160), located less than one mile west of the site (USGS 2004). The BES CSO rainfall network also has a rain gage at the Portland International Airport (Airport Way Raingage #2, Station 111; USGS 2004). In comparing the raw, uncorrected rainfall data from both stations for the past four years, it is seen that the difference in precipitation is relatively insignificant. For 2004 (to-date), the airport rain gage received approximately 3 inches more than the WPCL rain gage. For 2003, the airport rain gage received approximately 2 inches more precipitation than the WPCL rain gage. Conversely, the WPCL rain gage received more precipitation than the airport rain gage in the years 2002 and 2001 (USGS 2004).

USDA Texture Classification was determined from laboratory testing of the existing Site soils and topsoil from the proposed St. Helens, Oregon, source (also known as the Reichhold Site). The testing results indicated that the existing Site soils are sand, and the topsoil is a loam/sandy loam. For sensitivity analysis, input parameters that were varied were rooting depth, Kc, and soil augmentation with biosolids (resulting in texture change).

Ecolotree's 50% Design Report which includes discussions on all model input parameters, modeling results, and conclusions/recommendations is attached in Appendix A. The following table summarizes the percolation modeling results:

HYDRUS MODEL RUN DESCRIPTIONS AND AVERAGE ANNUAL WATER BALANCE RESULTS FOR 1992-2003

Run #	Type of Vegetation	Root Depth (feet)	Crop Coeff., Kc	Biosolids (blended into top 2 feet of existing cover)	2 Feet of Topsoil Applied	Precipitation (inches)	Runoff (inches)	Transpiration (inches)	Evaporation (inches)	Infiltration (inches)
McB 1	Existing grass	0.8	1			38.30	0.00	7.23	4.45	26.60
McB 2	Native grass mix	7	1		X	38.30	0.00	13.11	5.29	19.61
McB 3	Native grass mix	7	1	X	X	38.30	0.00	14.80	5.39	17.84
McB 4	Hybrid poplar forest	8	1.25		X	38.30	0.00	13.50	6.05	18.45
McB 5	Hybrid poplar forest	8	1.5		X	38.30	0.00	13.63	6.15	18.23
McB 6	Hybrid poplar forest	8	1.5	X	X	38.30	0.00	15.37	6.26	16.52
McB 7	Hybrid poplar forest	4	1.5	X	X	38.30	0.00	14.41	6.12	17.50
McB 8	Deciduous forest	5	1		X	38.30	0.00	12.75	7.38	17.92
McB 9	Deciduous forest	5	1	X	X	38.30	0.00	14.40	7.48	16.21
McB 10	Deciduous forest	6	1	X	X	38.30	0.00	14.62	7.52	15.98
McB 11	Deciduous forest	7	1	X	X	38.30	0.00	14.80	7.53	15.82
McB 12	Conifer forest	6	1		X	38.30	0.00	12.77	12.37	13.09
McB 13	Conifer forest	6	1	X	X	38.30	0.00	14.48	12.47	11.42
McB 14	Conifer forest	5	1	X	X	38.30	0.00	13.97	12.36	11.95

Based on the above modeling results, the following conclusions were developed by Ecolotree:

1. All of the ET cover options showed storm water infiltration, ranging between 11.4 inches/year for a mature conifer forest to 26.6 inches/year for existing conditions (shallow-rooted grasses).
2. Rooting depth had minimal impact on infiltration rates. Greater root depths reduced infiltration rates by < 0.5 inches per foot of root depth. This result is due to the sandy site soils, which have

very low water holding capacity and very high conductivities. For soils that are not as sandy as the site soils, greater rooting depth typically significantly reduces infiltration rates.

3. An increase in the growing season PET potential of an ET cover (higher crop coefficient) had minimal impact on infiltration rates. This result is due to the fact that little precipitation falls during the summer months, which results in substantial unused PET capacity.
4. Incorporation of biosolids into the top two feet of sandy site soils had a somewhat significant impact, reducing infiltration by approximately 1.7 inches/year (46,000 gallons/acre/year).
5. Increasing the topsoil thickness by another foot had very little benefit (less than 1 inch reduction in infiltration) in reducing storm water percolation through the cover. Note, this is based on preliminary model runs and wasn't carried forward into final runs.
6. Canopy interception potential of winter precipitation had the greatest impact on infiltration rates, and is the primary reason why a mature conifer forest is predicted to outperform the other ET cover options.

3.0 OVERVIEW OF EVAPOTRANSPIRATION COVERS IN HUMID ENVIRONMENTS

An ever-increasing body of information is available regarding the design and performance of ET covers at sites in arid, semi-arid, and humid environments. Although ET covers primarily have been constructed in arid and semi-arid environments, ET covers are also being used in humid environments (similar to the McCormick and Baxter Site) and have shown to be effective in substantially reducing percolation.

E & E attempted to identify significant publications and collect information related to the use of ET covers in humid environments. The following papers, projects, and studies were collected and reviewed:

1. United States Environmental Protection Agency (EPA) Alternative Cover Assessment Program (ACAP).
2. "Natural Covers for Landfills and Buried Waste", Victor L. Hauser, P.E., et al, *Journal of Environmental Engineering*, September 2001.
3. *Vegetated Landfill Covers and Phytostabilization – The Potential for Evapotranspiration-Based Remediation at Air Force Bases*, Victor L. Hauser, P.E. and Dianna M. Gimon, May 2001.
4. *Final Covers for Waste Containment Systems: A North American Perspective*, Craig Benson, University of Wisconsin-Madison, November 23 – 25, 1999.
5. Additional ET Cover Information, including the EPA Technology Innovation Program database on Alternative Landfill Cover Projects.

A brief discussion of the above information is provided in the following sections. For more detailed information, the reader should refer to the full publication(s).

3.1 Alternative Cover Assessment Program (Albright et al 2004, 2002; Benson et al 2004, 2002; Bolen et al 2001; EPA 2004)

In 1998, the United States Environmental Protection Agency (EPA) initiated the Alternative Cover Assessment Project (ACAP) to assess the hydrologic behavior of conventional (e.g., clay or synthetic lined, multi-layer) and alternative (e.g., ET) landfill final covers. As part of ACAP, conventional and ET covers were monitored, side by side, to assess the water balance for each. Specifically, the percolation rates from the base of the covers were monitored to assess the covers' ability to minimize infiltration.

The ACAP consisted of 11 sites in seven states with climates ranging from arid to humid. Three of the sites were located in humid environments: Omaha, Nebraska; Albany, Georgia; and Cedar Rapids, Iowa.

Ten conventional covers and fourteen (14) ET covers were evaluated, with side-by-side comparisons at eight of the sites. All of the covers were constructed with local soils. Since 2001, percolation, lateral flow, and surface runoff data have been collected. Meteorological parameters also were measured at each site using a weather station staged on site. Evapotranspiration was estimated as the difference between precipitation and the sum of the other components of the water balance (i.e., surface runoff, the change in soil water storage, lateral drainage, and percolation). Potential evapotranspiration (PET) was calculated using the Penman-Monteith method using climate data collected on site.

In monitoring surface water runoff from the alternative and conventional covers, it was found that surface water runoff was less for ET covers than for conventional covers. This is believed to be due to the rough surface and denser vegetation on the alternative cover providing greater resistance to surface flow.

Percolation data collected from ET covers constructed in humid environments showed that these covers transmitted the most percolation with average percolation rates ranging between 33.3 (6.1% of the precipitation) millimeters per year (mm/yr) and 159.6 mm/yr (18.4% of precipitation). The study found that nearly all of the percolation transmitted by the two ET barriers at the site in Omaha occurred when the actual soil water storage exceeded the predicted water storage capacity during some heavy rainfalls, thus following basic water balance principles. The ET cover constructed in Albany, on the other hand, was found to transmit percolation regardless of the soil water storage status. However, the data suggest that "the behavior of alternative covers in humid climates is likely to change in response to maturation of the plant community and pedogenesis". (Albright et al 2004)

In the 2004 paper summarizing the results of the ACAP project, the authors note that during the course of the Albany study, three distinct hydrologic periods were apparent (Albright et al 2004). The initial 6-month period had high percolation rates likely due to the vegetation establishing itself in the cover. The second hydrologic period was characterized by the rapid development of poplar trees and very low percolation rates. Towards the end of the second hydrologic period an extensive period of soil drying occurred due to a lack of precipitation. During the third hydrologic period, percolation was found to follow precipitation events. The authors of the 2004 paper believe that the increased percolation rates observed during the third period were the result of desiccation cracks or root channels penetrating through the entire cover during the previous drying period. (Albright et al 2004)

In a discussion with a co-author of the 2004 report regarding the third period percolation through the Albany ET cover, it was suggested that the desiccation cracks were likely a result of using sandy clay rather than a soil with more silt and sand. However, these courser grained soils would be expected to transmit more water because of their decreased water retention characteristics. The author also indicated that at humid sites, percolation can reasonably be expected to range between 50 mm/yr and 100 mm/yr. (Benson 2004)

3.2 Natural Covers for Landfills and Buried Waste (Hauser et al 2001a)

In this paper, the authors discuss vegetative covers and present a number of studies which show that the use of vegetation is an effective means of reducing infiltration of storm water.

The authors present five different studies verifying the effectiveness of vegetative covers around the United States. Cited was a series of short-term field experiments conducted throughout a variety of climates, including the Pacific Northwest, with annual precipitation amounts from 160 to 900 mm/year. These experiments evaluated water movement through soil covers for up to 8 years. The results showed that vegetative covers could minimize the amount of precipitation penetrating the waste.

Another study referenced was a 1939 report that contained the results of water balance experiments conducted between 1907 and 1936 at five locations throughout the Great Plains. According to the authors, "soil water records were completed for native sod grown on a silty clay loam soil for 21 years at Mandan, North Dakota, and on a very fine sandy loam soil during 25 years in North Platte, Nebraska". The facilitators of the 1939 study found that water never penetrated beyond the roots of the native sod. The other studies reviewed by the authors were conducted at arid sites. The data from these sites also show that vegetation slowed the percolation of water below the root zone.

Although the authors found many sites where vegetative covers appear to meet the regulatory requirements for a landfill cover, there were some that did not. The authors found that vegetative covers that did not meet landfill requirements typically resulted from "insufficient depths of soil to store precipitation and support healthy stands of perennial plants". The authors also indicated that over-compaction likely reduced the water-holding capacity of the soil and that high soil density may have reduced root growth.

Based on the information obtained by the authors' from the studies they reviewed, they recommend a set of requirements that should be met if a vegetative cover is going to be successful. At a minimum, the authors recommend that the soil used to construct the vegetative cover should be able to support rapid and prolific root growth throughout the cover, and the soil must be capable of holding enough water to minimize water movement below the cover during extreme or critical weather conditions. The soil should also have a nutrient store that is adequate to support plant growth via nutrient cycling, both immediately and in the future. The authors also emphasize that maintaining a soil bulk density between 0.928 tons/cy and 1.26 tons/cy {1.1 Mg/m^3 to 1.5 Mg/m^3) is important for maximizing root growth. The authors recommend planting a mixture of perennial native species and recommend that the surface slope should be great enough to prevent ponding. The surface should also be shaped to rapidly and completely drain surface water runoff without concentrating the flow.

The authors further state that construction of a vegetative cover as compared to a conventional cover is less expensive and the maintenance costs would be minimized due to ease of cover repair. If a depression, crack, or hole develops on a vegetative cover, filling it with soil, reestablishing the grade, then replanting can repair it. Overall, the authors conclude that vegetative covers are applicable for use throughout much of the United States; and if properly designed and installed, can effectively minimize percolation through the cover for extended periods of time. Furthermore, vegetative covers are designed to work with the forces of nature rather than attempting to control them. (Hauser et al 2001a)

3.3 Potential for Evapotranspiration-Based Remediation at Air Force Bases (Hauser et al 2001b)

In this study, the authors evaluated the potential for utilizing ET cover technology at over 109 Air Force Bases (AFBs) across the United States and classified 60 AFBs as affording good, fair, or marginal opportunities for using ET covers as part of the remediation approach. Because the success of an ET cover depends greatly on the climatic conditions present at the site, the authors utilized climatic factors to assess the use of ET covers at these AFBs.

The authors estimated the potential ET (PET) and actual ET (AET) at 60 United States AFBs, including the McChord AFB located in Tacoma, Washington (average annual precipitation of 40.9 inches). PET and AET were determined using the Environmental Policy Integrated Climate (EPIC) model. The PET is the maximum amount of water that plant systems can transfer back to the atmosphere. AET is typically less than PET because of factors such as water stress, nutrient deficiency, and hydrologic factors.

To use the EPIC model, the authors assumed that the same 6.6-feet thick soil cover was installed at all 60 AFBs; assumed that the vegetative cover consisted of a monoculture of native grasses with the potential to root two meters into the soil; and utilized the climate data already stored in the model for locations at or near the AFBs. The authors also assumed that the water table was at 100 feet below ground surface in order to simulate a condition where the plants only subsisted on precipitation stored in the soil. The authors noted that if they had used a diverse plant cover, the AET would be greater than with a monoculture of grasses.

The study showed that PET values are controlled primarily by climate input data, whereas the AET is influenced by soil and plant input data. Because PET is highly dependent on climate, the authors concluded that the PET analysis is most appropriate for assessing whether or not use of an ET cover at a particular site warrants further investigation. The authors then calculated the PET ratio for each of the 60 AFBs in their study to assess the appropriateness of using ET landfill covers at each AFB. The PET ratio is the ratio of the annual PET to the annual precipitation. The PET ratios were divided into three groups: good (PET greater than 1.5), fair (PET between 1.2 and 1.5), and marginal (PET less than 1.2). PET ratios greater than 1.5 indicated that there was a high probability of success at using plants for remediation. PET ratios between 1.2 and 1.5 indicate that an ET cover would likely be successful; however, a site-specific analysis of its appropriateness would be necessary. PET ratios less than 1.2 indicate that the prospects for successfully using an ET cover for remediation are limited.

Using the PET ratios, the authors determined that of the 60 AFBs evaluated in this study, 56 AFBs fell into the categories good and fair. The calculated PET ratio for the McChord AFB was 1.3 (fair rating), indicating that an ET cover would likely be successful.

Plotting the data for all 60 sites onto a map of the United States, the authors were then able to evaluate the PET ratios for another 42 AFBs based their location. Of those 42 AFBs, a total of 19 AFBs were found to be climatically suitable for ET cover usage, whereas the remaining 23 AFBs were found to fall into the marginal category. Because approximately 75% of the AFBs evaluated in this study were found to fall into the Good or Fair category, the authors concluded that climatic factors do not limit application of ET covers or phytostabilization at most AFBs across the country.

3.4 Final Covers for Waste Containment (Benson et al 1999)

This paper reviews the chronological development of final cover designs in North America and describes some of the lessons learned for many types of final covers, including compacted clay covers, composite covers, geosynthetic clay liners (GCLs), and ET covers.

Information was provided by the author, Dr. Craig Benson, P.E., showing that compacted clay covers are highly susceptible to failure as a result of desiccation cracking, frost, and differential settlement or a combination of the three mechanisms. Composite covers consisting of a layer of compacted clay and overlain by a geomembrane and a vegetated surface are more effective than compacted clay covers; however, frost intrusion can be a problem if a frost protection layer is not included in the construction of the cover. Also, if a drainage layer is not included in the construction of the composite cover, pore pressures can build up during precipitation and/or snowmelt and result in failures along the interfaces above the geomembrane.

Dr. Benson also reviewed the performance of GCLs and found that GCLs that are not protected by an overlying geomembrane are susceptible to cation exchange that can result in less swelling of the bentonite during re-hydration, desiccation cracks that do not heal, and large increases in hydraulic conductivity. Another potential problem with GCLs that the author mentions is instability due to the low drained shear strength of bentonite; therefore, reinforced GCLs are usually recommended.

Finally, Dr. Benson discusses ET covers and points out that ET covers are viewed as being "more harmonious with nature" and able to perform as well as composite covers and better than compacted clay covers. The author also states that desiccation cracking and frost damage can be a problem in ET covers; therefore, soils used to construct the ET cover should have a low potential for these problems. Soils with a low potential for desiccation cracking and frost damage include silty sands, silts, silty clayey sands, clayey silty sands, and similar materials.

3.5 Additional ET Cover Information

EPA's Technology Innovation Program (EPA 2004)

According to the EPA's Technology Innovation Program database, there are a total of sixteen (16) monolithic ET covers and two capillary barrier ET covers installed at humid sites around the United States. Table 3-1 (attached at the end of the memo) provides a description of the ET covers that have been constructed or are proposed for construction at humid sites around the U.S. For the purposes of this memorandum, a humid site is defined as a site that receives greater than 30 inches of precipitation annually.

Of the 16 monolithic ET covers presented in Table 3-1, four of the ET covers were included in Phase II of the ACAP. Performance data from the ACAP study show that ET covers in humid environments will typically have between 50 and 100 millimeters (1.96 and 3.94 inches) of annual percolation. Anything less than 50 millimeters of annual percolation should not be expected for an ET cover installed at a humid site.

Performance data is not available for any of the other non-ACAP sites listed on Table 3-1, with the exception of the Duvall Landfill in Duvall, Washington.

An ET cover was constructed at the Duvall Custodial Landfill in Duvall, Washington, in April 2000 (King County 2004). The site receives, on average, approximately 47 inches of annual precipitation (EPA 2004). The cover was constructed by placing 72 inches of loam over 13 acres. The site has been continuously monitored since April 2000 to assess the performance of the cover. In the cover performance monitoring report, the following conclusions were made regarding the performance of the ET cover at the Duvall Landfill (King County 2004):

- The survival rate of trees planted at the site is reported to be approximately 98 percent; however, the survival rate appeared to be less than this amount during the site visit.
- Differences in tree growth observed at the site can be attributed to differences in soil compaction, soil amendments, and tree type.
    - Tree growth in areas where soil was more compacted than the rest of the cover show less growth than other areas of the site. Analysis of nutrient availability indicated that there was no difference between the different areas of the site, but density tests revealed that the west half of the cover, where tree growth was less, was 5 percent more dense than the rest of the cover.
    - An organic biosolid amendment product called GroCo was applied to a test section of the cover and found to enhance the growth of trees in this area. Another benefit to using the GroCo realized during this experiment was that the GroCo test section had less of a vole problem than the rest of the cover.

- Four tree varieties were planted on the cover, and it was found that one of the poplar varieties are consistently 30 to 40% smaller than the rest of the trees planted at the site. No explanation as to why this is the case was offered.

- Insect and disease damage to the trees has not been a problem at this site. This is attributed to frequent insect and disease scouting activities (e.g. biweekly scouting). The authors of the report feel insect scouting is more effective than preventative insect spraying because insects have not been a problem.

- Voles are a problem at the site with the exception of the GroCo test plot. Vole holes have not been observed in the GroCo test plot for the two years since applying GroCo to the cover; however, vole damage appears to be increasing in 2004. Adding more GroCo to the cover may control this problem. Raptor perches and owl nesting boxes also have been installed around the facility in an effort to control the voles naturally.

- Deer have been using trees to rub their antlers against as well as to feed on; however, the damage sustained by these trees has not resulted in the death of any of the trees.

- Cedar trees have been planted in the cover in an effort to increase the amount of evapotranspiration during the winter months and to transition the site to "a natural woodland". The cedar trees were planted in the spring of 2002 and appeared to be healthy one year later.

- Weed management has primarily involved manually protecting the trees and grubbing around the tree base. Weed whacking and mowing also has controlled the growth of weeds. King County has found that these methods are more effective than herbicides. It was also observed that as the trees mature, they out-compete the weeds.

- As the trees have matured, the need to irrigate the trees has diminished. Irrigation was reduced by 5 inches per year by the year 2001. No irrigation water was supplied to the site in 2002.

- Annual precipitation at the site has varied widely over the years, from 19 inches in 2001 to 41 inches in 2002. Comparing the soil moisture data from spring 2000 to spring 2003 shows that the poplar trees have created an additional 6 inches of soil moisture holding capacity. The amount of deep percolation for water years 2001, 2002, and 2003 is 1.6 inches, 11.6 inches, and 4.2 inches, respectively. The low amount of deep percolation in 2001 is attributed to the lack of precipitation that year, while the decrease in deep percolation between 2002 and 2003 is attributed to an increase in the available water holding capacity created by tree transpiration. This information was obtained using site-specific data.

<u>Avtex Fiber Superfund Site (Gross 2004)</u>

There are also a number of ET covers constructed in humid environments around the United States that are not included in the EPA's Technology Innovation Program database. One of which was constructed in Front Royal, Virginia, as part of the remedial action at the Avtex Fiber Superfund Site. An ET cover was constructed over fly-ash basins at this site to reduce the infiltration of precipitation through the cover into the closed units. Performance data is not collected for this ET cover, as it was not required. However, in a discussion with the project engineer, there are a number of ways to collect performance data without installing a lysimeter. These include using cone penetrometer testing and collecting core samples from the cover and analyzing them for soil moisture content.

Although percolation was not measured for the Avtex Fiber ET cover, the modeling performed by the design engineers indicated that in areas of the cover where more trees were planted, percolation would likely be a little over 3.5 inches annually. In the areas where grass is the predominant vegetation, annual percolation was estimated at a little over 5 inches per year. Modeling was performed using the UNSAT-H model and climate data for the wettest 30-year period. Average annual precipitation over the 30-year period modeled for the Avtex Fiber ET cover was 37 inches per year.

4.0 COMPARITIVE ANALYSIS

DEQ has proposed to use an ET cover to cap the upland portion of the McCormick and Baxter Site. To address EPA's concerns that an impermeable cover may be more appropriate for that area within the barrier wall, this section has been developed to provide a cursory comparative analysis between an ET cover and an impermeable cover. This analysis assumes a multi-layer, RCRA-type impermeable cap would be used (see Section 4.2 for cap details).

The following sections discuss the advantages and disadvantages of each cover type (ET vs. impermeable), specifically with respect to predicted percolation; construction; operation and maintenance; future land use; costs; and schedule.

4.1 Predicted Percolation

As discussed in Section 2.0, the predicted percolation of an ET cover, as determined by HYDRUS-1D modeling, ranges from 11.42 inches per year (for a mature conifer forest rooted to six feet bgs) to 26.60 inches per year (for the existing grass rooted to 0.8 feet bgs). The model runs used an average precipitation of 38.30 inches per year. For more detailed information pertaining to the ET cover modeling, see Appendix A.

The ET cover modeling estimated greater amounts of percolation than would be expected from the literature review presented previously. It is not clear whether the ET cover modeling overestimates or more accurately estimates percolation for the design scenarios for the McCormick and Baxter soil cap.

Percolation through an ET cover is expected to initially be elevated for the first few years or until vegetation has been sufficiently established. This "start-up" period is dependent on the vegetation selected and soil agronomy (e.g., organic matter, nutrients). For this reason, Ecolotree has recommended that the soil be amended to maximize plant growth rates. Furthermore, Ecolotree has recommended that a vegetation mix of poplars and native conifers be planted within the barrier wall limits. This would combine the benefits of fast growing, deep rooting poplars during the start-up period with the higher canopy interception performance of conifers once plant maturity is reached. After plant maturity, percolation through an ET cover is expected to remain relatively constant, or even decrease with time as the vegetation becomes further established.

Undoubtedly, the use of an impermeable cover will result in less percolation. As presented in the Soil Cap Design Criteria Report (E & E 2004), a geosynthetic clay liner (GCL) overlain by a drainage layer is predicted by the HELP model to percolate 0.062 inches per year, assuming an average precipitation of 40.05 inches per year. It should be noted, however, that the sole use of a GCL without an overlying geomembrane (e.g., HDPE flexible membrane liner) is not recommended. Several sources indicate that GCLs that are not protected by an overlying geomembrane are susceptible to cation exchange that can result in less swelling of the bentonite during re-hydration, desiccation cracks that do not heal, and large increases in hydraulic conductivity. For the purposes of this analysis, however, E & E is assuming that a multi-layer system would achieve percolation less than or equal to that predicted for a properly functioning GCL, or 0.062 inches per year. This value would be assumed for a newly constructed impermeable liner system. With time, however, a synthetic liner system will be susceptible to deterioration, and an increase in percolation would be expected with time.

Another point to consider is that a portion of the area within the barrier wall (2.9 acres along the bank layback area or sixteen percent of the full barrier wall area) is required to be managed as a vegetated riparian habitat, as stipulated by the Biological Opinion prepared by NOAA's National Marine Fisheries Service (NOAA Fisheries 2004) for the sediment cap construction. As such, placement of an impermeable cover within this 2.9 acre area is not permitted. Only that area within the barrier wall above the bank layback greenway limits (14.94 acres) could be capped with an impermeable cover; therefore, a portion within the barrier wall would remain permeable, thereby reducing the effectiveness and intent of an impermeable cover. On the other hand, installation of an ET cover within the barrier wall would, in essence, be an extension of the vegetated bank (i.e., consistent with the bank layback area) and could be managed as one unit.

4.2 Construction

This section compares the construction requirements for an ET cover and an impermeable cover. In general, the construction of an ET cover is considerably less complicated than construction of an impermeable since there are fewer layers incorporated into an ET cover.

<u>ET Cover Construction</u>
Construction of an ET cover, similar to what is proposed for construction at the Site, would involve grading existing site soil (to achieve positive drainage within the barrier wall) and potentially augmenting the existing site soil with amendments to maximize plant growth. A synthetic demarcation layer allowing root penetration would then be placed over the existing soil followed by a layer of topsoil to achieve the 24-inch cap thickness as required by the ROD. The final construction step involves planting the vegetation (e.g., trees, shrubs, and grasses).

A typical detail illustrating the above layers is included as Figure 4-1. A conceptual plan for construction of an ET cover at the Site is included as Figure 4-2.

<u>Impermeable Cover Construction</u>
Construction of a conventional cover is considerably more complex. The following construction details assumes a multi-layer, RCRA-type cover system, similar to that installed in 1999 at the Western Processing Superfund Site, located in Kent, Washington.

Construction would begin by placing a leveling layer over the existing soils to achieve a two percent subgrade slope required for drainage of the water collected above the impermeable layers. The next step involves installation of impermeable layers consisting of a geosynthetic clay liner (GCL) overlain by a flexible membrane liner (FML; e.g., HDPE geomembrane). Drainage layers, typically consisting of a sand layer underlain by a geonet composite material, would then be constructed atop the impermeable layers. With an impermeable cover, a drainage layer is required in order to remove storm water that accumulates above the underlying impermeable layers. Stormwater management facilities (e.g., collection piping, conveyance piping, and manholes/cleanouts) would also need to be constructed to remove the water collected from the drainage layer. Following drainage layer installation, a biotic layer consisting of gravel and cobble, is constructed in order to prevent rodents and other burrowing animals from penetrating the impermeable layers. The final layer to be constructed is the vegetative layer. The purpose of the vegetative layer is to minimize erosion of the cover by wind and storm water. The vegetative layer would be constructed by installing a geotextile filter fabric atop the biotic layer, then placing a layer of topsoil above the filter fabric. The filter fabric is necessary in order to prevent fines (contained with the topsoil) from migrating downward into the drainage layers, which would compromise the drainage layers' functionality. After placing the topsoil, the cover would then be seeded with native grasses. Deeper rooted vegetation (e.g., trees, shrubs) could not be planted atop an impermeable cover.

A typical detail illustrating the above layers is included as Figure 4-1. A conceptual plan for construction of an impermeable cover at the Site is included as Figure 4-3.

Other Considerations

Import Soil and Compaction. As previously noted, an impermeable cover is required to have a slope of at least 2% to allow storm water drainage and prevent water accumulation on the cover. Constructing a 2% slope at the Site would require an increased quantity of soil to be imported to the site.

An ET cover, on the other hand, does not function as a water collection/drainage system that requires a minimum slope to remove the water. Rather, an ET cover functions as a "sponge and pump" system, where the water is actually encouraged to be stored (i.e., "sponge") in the soil matrix until evapotranspiration (i.e., "pump") occurs. As such, maintaining a minimum slope on an ET cover is not a necessary component of its functionality. A positive slope (approximately 0.5%), however, was incorporated into the conceptual design in order to prevent ponding from occurring within the barrier wall limits.

Since maintaining a 2% slope on an ET cover is not a necessary component of its functionality, less soil would need to be imported to the site to construct the cap subgrade (for estimated subgrade fill quantities, see Appendix B – Cost Estimate). Similarly, reduced compaction efforts would be required to construct the ET cover subgrade layer. Over-compaction of ET cover layers can reduce the cover's capacity to hold water and support vegetation. Root growth, which is essential to the cover's ability to evapotranspire, is severely impeded in over-compacted soils (Hauser et al 2001a). On the other hand, an increased compaction effort is required for construction of the leveling layer (i.e., subgrade) of an impermeable cover in order for the required 2% slope to be maintained, thereby reducing future settlement of the overlying layers.

Weather Constraints. While construction of an ET cover can proceed continuously (with downtime for periods of heavy rain), impermeable cover construction must essentially stop until reliably dry weather over extended periods can be predicted. This is because a GCL is hydrophilic. It will absorb water from precipitation or from damp underlying soil. Unless it is immediately covered with a sufficient layer of dry soil or another layer, hydration will cause the GCL to over-expand, making it ineffective as an impervious barrier. In addition, once a GCL is fully hydrated (without any confining pressure or normal loads over it), the product is assumed to be hydrated to the point that it can no longer be installed without excessive thinning and must be removed (Mackey 1997).

Additionally, the thermal welding process (e.g., via fusion hot wedge welding) used on a FML should be performed in the dry. FML manufacturers have indicated that if moisture is present during seaming, the welds may cool to quickly allowing the seams to peel apart, resulting in seam failure.

4.3 Operation and Maintenance

Both ET and impermeable covers have similar failure modes that would require maintenance and repair. However, the severity of these modes and required repair vary depending on the cover type.

Operation requirements for both cover systems typically include routine inspections of the cover to assess the need for maintenance. Inspections typically involve assessing the cover for stability; excessive settlement; erosion damage; health of the vegetation; damage resulting from freezing and/or drying; and animal and/or human damage (ITRC 2003).

Maintenance efforts and associated costs for an ET cover are typically much lower than an impermeable cover since ET covers are relatively self-renewing (Hauser et al 2001a). If a depression, crack, or a hole develops in an ET cover, repair would simply involve re-establishing the grade and replanting the vegetation (Hauser et al 2001a). Repair of an impermeable cover (similar to the construction of one), is more complex due to the number of layers involved and the increased labor associated with repair of the geosynthetic materials (e.g., FML, GCL, geonet).

Stability

Problems with foundation or slope stability can result in damage to a cover system (ITRC 2003). Foundation instability typically results from foundation soils not having enough shear strength to withstand loads applied by the overlying material. Excessive loads, water buildup, excessively steep slopes, or inadequate foundation shear strength typically causes inadequate foundation shear strength (e.g. weak soils, shallow groundwater, erosion or excavation of soils at the toe of the cover; ITRC 2003) and can lead to cover failure.

Slope stability is not a significant concern for capping the upland portion of the Site since steep slopes are not present. Furthermore, the cover will not be constructed over waste that is prone to shifting and moving. However, if an impermeable cover is not well drained, it is more likely to fail because of stability issues than an ET cover.

Settlement

Excessive settlement can damage a cover and result in several problems. Problems caused by excessive settlement include the following:

- Ponding on the cover. This can lead to increased infiltration, water buildup, and cover instability.
- Cracking of the cover. This can lead to increased erosion and infiltration that ultimately leads to instability.
- Damage to the storm water management system. This can result in concentrating storm water runoff areas in areas that are not resistant to the erosive forces of this concentrated flow.

Settlement in an ET cover is typically less common than in an impermeable cover (Gross 2004). Settlement is not expected to be a big concern at the site since the cover is not being constructed over waste that can shift and move. However, the site is located in a seismically active area. Seismic activity can result in the same impacts to the cover that settlement would cause; therefore, inspection of the cover would be required immediately following a seismic event (Magnuson 1995). Seismic activity can result in large tears in geomembranes and can result in displacement at cover interfaces (Magnuson 1995).

Erosion

Erosion can compromise the integrity of the cover leading to excessive percolation, erosion failure, or both (ITRC 2003). Erosion of a cover can be caused by both wind and water. Maintaining a vegetative cover on the soil and, in some instances, by installing additional protective measures in areas where storm water may tend to accumulate, minimizes erosion. Additional protective measures that can be installed in storm water collection areas include placing riprap, erosion control matting, or other types of linings geared toward minimizing erosion (ITRC 2003).

The rough surface and denser vegetation associated with an ET cover would likely provide greater resistance to surface flow, resulting in less surface water runoff and erosion than an impermeable cover (Albright et al 2004).

Vegetation

The first few years after completing construction of an ET cover are critical for establishing vegetation (ITRC 2003). Part of the operation and maintenance procedures for an ET cover during the startup period (i.e., first few years after its construction) may involve irrigation to promote rapid, healthy growth. Once vegetation is established, irrigation measures could be discontinued. As part of the ongoing O&M, the cover vegetation should be inspected once or twice per year for burned areas, overall plant vigor, excessive grazing, disease or pests, and weed infestation (ITRC 2003). Grass installed as part of either an ET or impermeable cover would require mowing to reduce the potential for fire.

Gradual and catastrophic changes in vegetation can impact an ET cover's performance by affecting the evapotranspiration and erosion potential. Fire, drought, insects, disease, and animals can alter vegetation negatively (Albright et al 2004). Vegetation loss is a more significant problem with ET covers than impermeable covers since its performance depends on having healthy stands of vegetation. Loss of vegetation on an impermeable cover leaves that part of the cover prone to erosion but typically does not impact its performance.

Weather Impacts

When using GCLs as part of the impermeable cover, it is important to consider the potential for frost or desiccation damage (Benson 1999). Although frost is not as big an issue in the Pacific Northwest, desiccation can be an issue. Although it has been determined that GCLs are more resilient to desiccation damage than compacted clay, there is evidence that desiccation does impact the hydraulic conductivity of GCLs (Benson 1999). Studies have shown that the exchange of divalent cations in the natural pore waters (e.g. magnesium and calcium) for sodium in the bentonite eventually leads to bentonite being unable to swell sufficiently to close cracks that form as a result of desiccation (Benson 1999). Therefore, if a GCL is exposed to wet-dry cycling and is not protected from cation exchange by placing them underneath a geomembrane, they will eventually fail (Benson 1999).

Desiccation in an ET cover can also negatively impact its hydraulic conductivity. The ET cover installed in Albany, Georgia (as part of the ACAP) developed desiccation cracks in response to a drought that occurred during the second year of the project. The amount of percolation through this cap increased significantly as a result of the desiccation cracking (Albright 2004). This particular cover was constructed of sandy clay. Had the cover been constructed of soil with a low potential for desiccation cracking (e.g. silty sands, silts, silty clayey sands, and clayey silty sands), less cracking likely would have been observed (Benson 1999). The soil proposed for use in constructing an ET cover at the McCormick and Baxter Site is a loam (mix of sand, silt, and clay); thus, desiccation cracking is less likely to occur.

Repairing desiccation cracking in an ET cover would require significantly less effort than that of an impermeable cover. Repair of a desiccated ET cover would simply involve replacing the soil in the area and re-vegetating. Repair of a desiccated impermeable cover (i.e., GCL) would involve excavating down to the damaged portion, replacing the damaged portion with a patch, then replacing all overlying layers. Furthermore, identification of a desiccated area in an ET cover is also usually less onerous, as visual evidence of the damage can been seen from the surface.

Animal Damage

Burrowing animals can present a problem for both ET and impermeable covers, as they generate preferential flow pathways for water to percolate through the cover. However, with an ET cover, limited amounts of burrowing animals within the cap do not necessarily present as big a problem as they would with an impermeable cover. For example, a single hole in an ET cover would only increase the percolation through that area occupied by the hole. A single hole in an impermeable cover, on the other hand, could drain a much larger area of the cover, as the hole could act as a funnel (i.e., preferential pathway) for a greater portion of drainage layer (drainage amount would depend on the size and location of the hole).

Repair of holes in an ET cover would also require less effort, as previously discussed (i.e., fill and re-vegetate). A small hole in an ET cover can also be self-healing, as surrounding soil and roots could eventually fill the openings with time. For an impermeable cover, any animal burrow through the cover would require immediate repair, as the cover is not self-healing.

In some instances, foraging deer can inhibit the growth of trees on an ET cover (Gross 2004), thereby reducing the effectiveness of the cover. Animal trails, resulting in over-compaction and stressed vegetation, can also become a problem on an ET cover if not remedied.

<u>Long-Term Operation and Maintenance</u>

"ET landfill covers are inexpensive, practical, and easily maintained biological systems that will remain effective over extended periods of time—perhaps centuries—at low cost" (Hauser et al 2001b). ET covers are expected to gain function and capacity with time following installation. During the first few years (while the vegetation matures), ET covers typically require increased O & M. However, as ET covers mature, O & M will drop off, after which it is expected to remain constant.

Impermeable covers, on the other hand, are more susceptible to degradation and other problems over time; therefore, O & M is expected to increase with time. Once an impermeable cover is installed, its performance never improves with time.

4.4 Future Land Use

As described in the Soil Cap Design Criteria Report (E & E 2004), the current proposed future use of the Site is a "managed open space, such as a park or natural area", consistent with the recommendations of the Land Reuse Advisory Committee. Furthermore, the Committee recommended that the cap be designed, to the extent feasible, to accommodate future development of the Site as a permanent park to include a variety of active and passive recreational uses and to accommodate "complementary non-recreational uses". The City of Portland has also strongly expressed that the Site have maximum flexibility for future development.

An ET cover would undoubtedly allow greater vegetation diversity (e.g., hardwood species, shrubs, and other deep rooting plants) than an impermeable cover (e.g., grass and flowers only) if a natural area is desired. However, an impermeable cover could be developed into sports fields or accommodate other recreational uses where a grass-vegetated surface would be used.

Future development (e.g., construction of buildings or other structures) on an impermeable cover would also be more complex and costly than development on an ET cover. Any structure penetrating an impermeable cover (e.g., building foundation) would need to be properly tied into the synthetic liner system (i.e., booted), and subsurface drainage around the structure would need to be considered. On the other hand, structures could be placed on an ET cover without much additional effort than what would normally be expected.

4.5 Costs

Cost estimates were developed for construction of an ET cover and an impermeable cover at the Site. The estimated construction cost for an ET cover is approximately $4,350,000. An impermeable cover is estimated to cost $7,550,000 or approximately 1.7 times that of an ET cover (note, both estimates also include costs for preparatory work items such as utility and well abandonment; structure removal; and capping the site entrance area with asphalt). The majority of the cost data used to develop the estimates was obtained from R.S. Means Heavy Construction Cost Data (18th Edition, 2004).

Construction cost summary tables and supporting detailed cost worksheets (with all assumptions listed) for both cover systems are included in Appendix B. Note, upon completion of the Upland Cap Final Design, a final cost estimate will be developed.

4.6 Completion Schedules

Completion schedules were developed to estimate the time required to design and construct both an ET cover and an impermeable cover (see Appendix C). The completion schedules were divided into the four main elements associated with any construction project: Design, Procurement, Preparatory Work, and Construction. Note, both schedules are constrained to varying degrees by expected weather conditions at the Site and by ongoing construction of the sediment cap. Expected weather conditions dictate when construction of the covers can begin and are therefore on the critical path for project completion. Because of the on-going construction of the sediment cap, some of the preparatory work needed to construct the covers cannot be performed until the current construction contractor is demobilized from the Site.

Design

The pre-final design (approximately 90% complete) of an ET cover is scheduled to be complete by mid-July 2004. After a 1-month review and comment period by the project team, the final design could be completed by September 6, 2004. The pre-final design includes design of preparatory work elements as well as the design of the cover. Preparatory work includes the following work items: abandoning select monitoring wells; demolition of the remaining structures at the site; abandoning and removing utilities; rebuilding the paved area where the site trailers are currently located (to provide a two-foot cap over this area); rerouting electrical and water lines to the site trailers; and construction of a new shop building.

In developing a schedule for the design of an impermeable cover, it was assumed that it would only cover the area within the barrier wall to the east of the bank layback greenway (14.94 acres), and that a two-foot soil cover would be placed over the remainder of the site (19.07 acres). As the pre-final design for the ET cover is scheduled to be completed by mid-July 2004, the design of an impermeable cover was assumed to start immediately after submitting the ET cover prefinal design.

There is a greater effort involved with developing the design of an impermeable cover. An impermeable cover's storm water runoff and collection requirements change radically from that of an ET cover. An impermeable cover incorporates more layers, including geosynthetic membrane layers (i.e., GCL and FML), and drainage layers. In order to allow the team an opportunity to review the design, a conceptual design stage (approximately 50% completion) was included so the team could review the design while the prefinal design was being completed. The conceptual design was assumed to take one month to complete and would be submitted for review by August 24, 2004. The conceptual design would not include details and specifications. Work on the pre-final design would continue for another 2 months after submitting the conceptual design. Comments received during this time would be incorporated into the prefinal design. The prefinal design was assumed to be submitted for an expedited review and comment period (3 weeks) on October 4, 2004. It was assumed to take one month to incorporate comments into the final design. The final design of the impermeable cover is estimated to be completed by November 22, 2004.

Procurement

The procurement schedules for both covers are essentially equivalent. The procurement period would begin before the final designs are complete. The time required for procurement includes periods for document approval by the Oregon Departments of Justice and of Administrative Services. A bid period of 6 weeks and a bid evaluation and award period of 4 weeks are assumed for both cover types. A contract award by February 15, 2005, is needed in order to begin construction activities by March 2005.

Preparatory Work

The preparatory work for both the ET cover and the impermeable cover are the same. The preparatory work items will be implemented as subcontracts to E & E. These work items will be accomplished in the late fall of 2004 and winter of 2005.

Construction

For both designs, the first month after awarding the construction contract would be utilized in preparing and reviewing contractor submittals. March 15, 2005 was selected as a date when the normal winter precipitation slows to a point that productive earthwork could commence.

As shown in Appendix C, the ET cover construction is predicted to be completed by early July 2005 (except for tree plantings, which would be postponed until the late fall of 2005 due to plant mortality concerns). The ET cover construction time was estimated using R.S. Means unit price estimating guides and engineering judgment.

The impermeable cover is predicted to be completed by the end of November 2005. To estimate the time to construct the impermeable cover, construction times similar to what was performed at the Western Processing Superfund Site (Kent, Washington) were used. The surface areas of the two impermeable cover systems are approximately the same (15 acres for McCormick and Baxter Site vs. 13 acres for the Western Processing site); and the anticipated number and type of layers assumed for the McCormick and Baxter impermeable cover are also similar to those constructed at the Western Processing site.

Note, the author and principal reviewer of this memorandum were both involved in overseeing the construction of the impermeable cover at the Western Processing site. During construction of this cap, there was virtually no downtime. Thus, because the time estimated to construct an impermeable cover at the McCormick and Baxter Site is based on ideal conditions (Western Processing), the assumed construction schedule does not include downtime for inclement weather or other complications that could delay construction completion.

Furthermore, while construction of an ET cover can proceed continuously (with downtime for periods of heavy rain), impermeable cover construction must stop until reliably dry weather over extended periods can be predicted. Stopping construction of an impermeable cover during wet weather is necessary since the GCL is hydrophilic. Unless the GCL is immediately covered with a sufficient layer of dry soil or another layer, hydration will cause the GCL to over-expand and swell, rendering it ineffective as an impervious barrier. Additionally, the thermal welding process used for geomembrane installation should also be performed in dry weather. FML manufacturers have indicated that if moisture is present during seaming, the welds may cool to quickly allowing the seams to peel apart, resulting in seam failure.

5.0 REFERENCES

Adderley, Virgil, July 6, 2004, Combined Sewer Overflow Program, City of Portland Bureau of Environmental Services, Portland, Oregon, electronic mail correspondence with Suzanne Dolberg, P.E., Engineer, Ecology & Environment, Inc., Seattle, Washington, regarding: Questions regarding precipitation data the BES CSO program uses.

Albright, William H., Craig H. Benson, Glendon W. Gee, Arthur C. Roesler, Tarek Abichou, Preecha Apiwantragoon, Bradley F. Lyles, and Steven A. Rock, 2004, "Field Water Balance on Landfill Final Covers", submitted to the *Journal of Environmental Engineering*, currently in review.

Albright, William H., Glendon W. Gee, Glenn V. Wilson, and Michael J. Fayer, October 2002, *Alternative Cover Assessment Program Phase I Report*, prepared for the United States Environmental Protection Agency under Contract No. 44-0000-2038 by the Division of Hydrologic Science, Desert Research Institute, University and Community College System of Nevada, Publication Number 41183.

Benson, Craig H., Ph.D., P.E., April 29, 2004, Professor, University of Wisconsin-Madison, Madison, Wisconsin, electronic mail correspondence with Suzanne Dolberg, Engineer, Ecology & Environment, Inc., Seattle, Washington, regarding ACAP performance evaluation.

Benson, Craig H., William H. Albright, Arthur C. Roesler, and Tarek Abichou, February 24, 2002, *Evaluation of Final Cover Performance: Field Data from the Alternative Cover Assessment Program (ACAP)*, presented at the WM '02 Conference held in Tucson, Arizona, February 24 – 28, 2002.

Benson, Craig H., November 23, 1999, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin, *Final Covers for Waste Containment Systems: A North American Perspective*, presented at the XVII Conference of Geotechnics of Torino, in Torino, Italy.

Bolen, Michael M., Arthur C. Roesler, Craig H. Benson, and William H. Albright, September 2001, *Alternative Cover Assessment Program: Phase II Report*, Geo Engineering Report 01-10, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin.

Ecology & Environment, Inc., February 2004, *Soil Cap Design Criteria Report*, prepared for Oregon Department of Environmental Quality, Portland, Oregon.

Gross, Beth, May 4, 2004, GeoSyntec Consultants, Austin, Texas, personal communication with Suzanne Dolberg, Engineer, Ecology & Environment, Inc., Seattle, Washington, regarding the ET cover at the Avtex Fiber Superfund Site.

Hauser, Victor L., P.E., Barron L. Weand, and Marc D. Gill, P.E., September 2001(a), "Natural Covers for Landfills and Buried Waste", *Journal of Environmental Engineering*, pp. 768 – 775.

Hauser, Victor L., P.E. and Dianna M. Gimon, May 2001(b), *Vegetated Landfill Covers and Phytostabilization – The Potential for Evapotranspiration-Based Remediation at Air Force Bases*, prepared for Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, TX.

Hauser, Victor L., P.E., Dianna M. Gimon, and Danny R. Jackson, September 2000, *Golf Courses on Air Force Landfills*, prepared for Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, TX.

Interstate Technology Regulatory Council (ITRC), May 13, 2004, "Design, Installation and Monitoring of Alternative Final Landfill Covers", internet-based training program sponsored by ITRC and the EPA Office of Superfund Remediation and Technology Innovation.

_____, December 2003, *Technical And Regulatory Guidance for Design, Installation, and Monitoring of Alternative Final Landfill Covers*, prepared by the ITRC Alternative Landfill Technologies Team.

Mackey, Robert E., January 1997, "Geosynthetic Clay Liners, Part Five: Design, Permitting and Installation Concepts", *Geotechnical Fabrics Report*, pp. 34-39.

Magnuson, Anne, April 1, 1995, "Shake, rattle & hold: landfill stability in seismic regions", *American City & Country*, http://www.americancityandcounty.com/mag/government_shake_rattle_hold/.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries), March 2004, *Biological Opinion for Construction of the Sediment Cap at the McCormick and Baxter Creosoting Company Site*, submitted to EPA, Oregon Operations Office.

United States Environmental Protection Agency (EPA), April 21, 2004, Alternative Landfill Cover Project Profiles, developed by the Office of Solid Waste and Emergency Response, Washington, D.C., as part of the Technology Innovation Program, http://www.clu-in.org/products/altcovers/, last updated February 2, 2004.

United States Environmental Protection Agency and the State of Oregon Department of Environmental Quality (EPA/DEQ), August 2002, *Explanation of Significant Difference (OU3 – Final Groundwater)*, prepared for the McCormick & Baxter Creosoting Site, Portland, Oregon.

______, March 1998, *Amended Record of Decision*, prepared for the McCormick & Baxter Creosoting Site, Portland, Oregon.

______, 1996, *Record of Decision*, prepared for McCormick & Baxter Creosoting Company, Portland, Oregon.

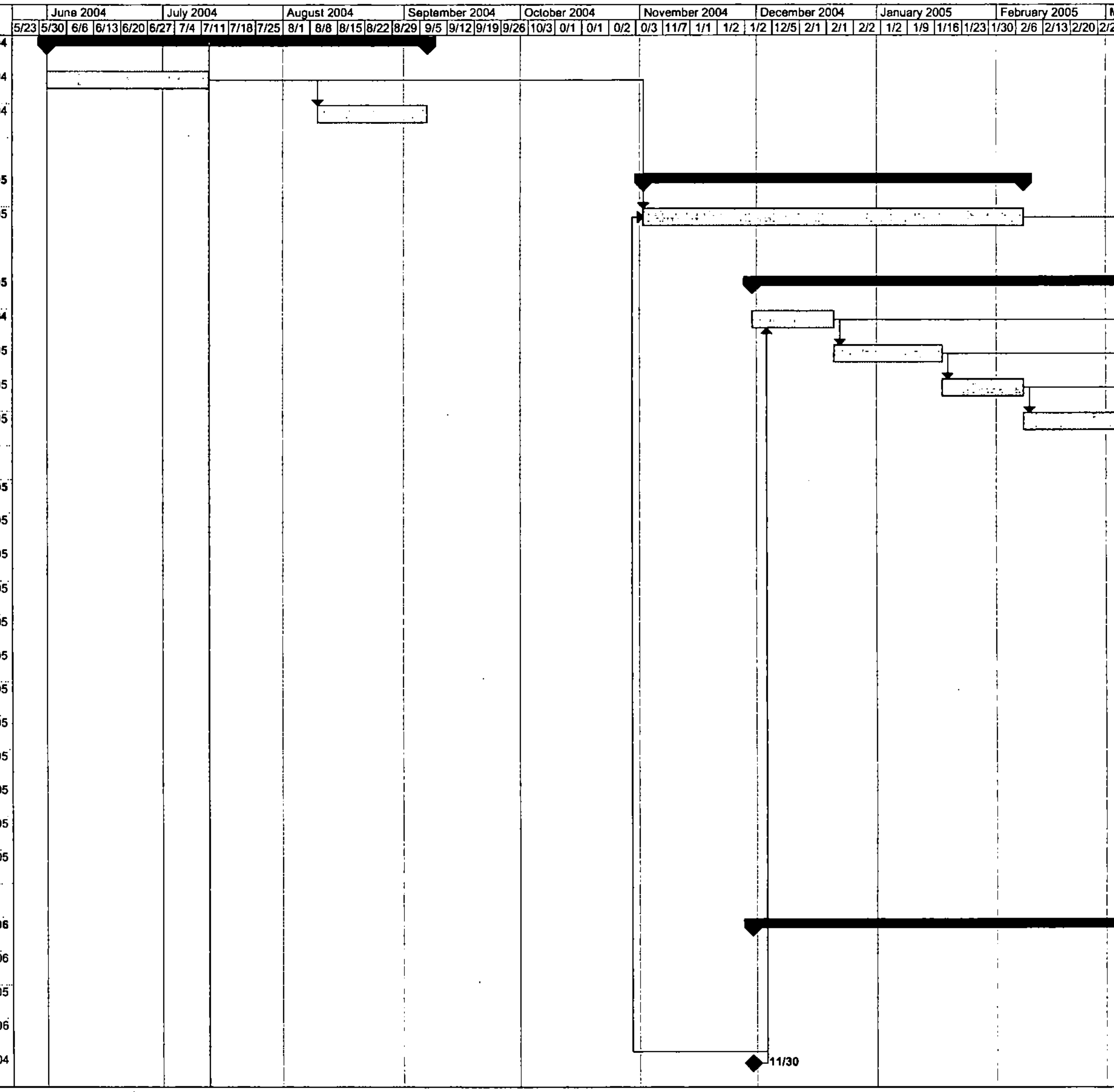
United State Geological Service (USGS), July 7, 2004, *City of Portland HYDRA Rainfall Network*, http://or.water.usgs.go/non-usgs/bes, last updated July 7, 2004.

Western Regional Climate Center (WRCC), May 2004, *Portland WSFO, Oregon (356751) Period of Record Monthly Climate Data*, http://www.wrcc.dri.edu/cgi-bin/climain.pl?orport, last updated March 31, 2004.

TABLES

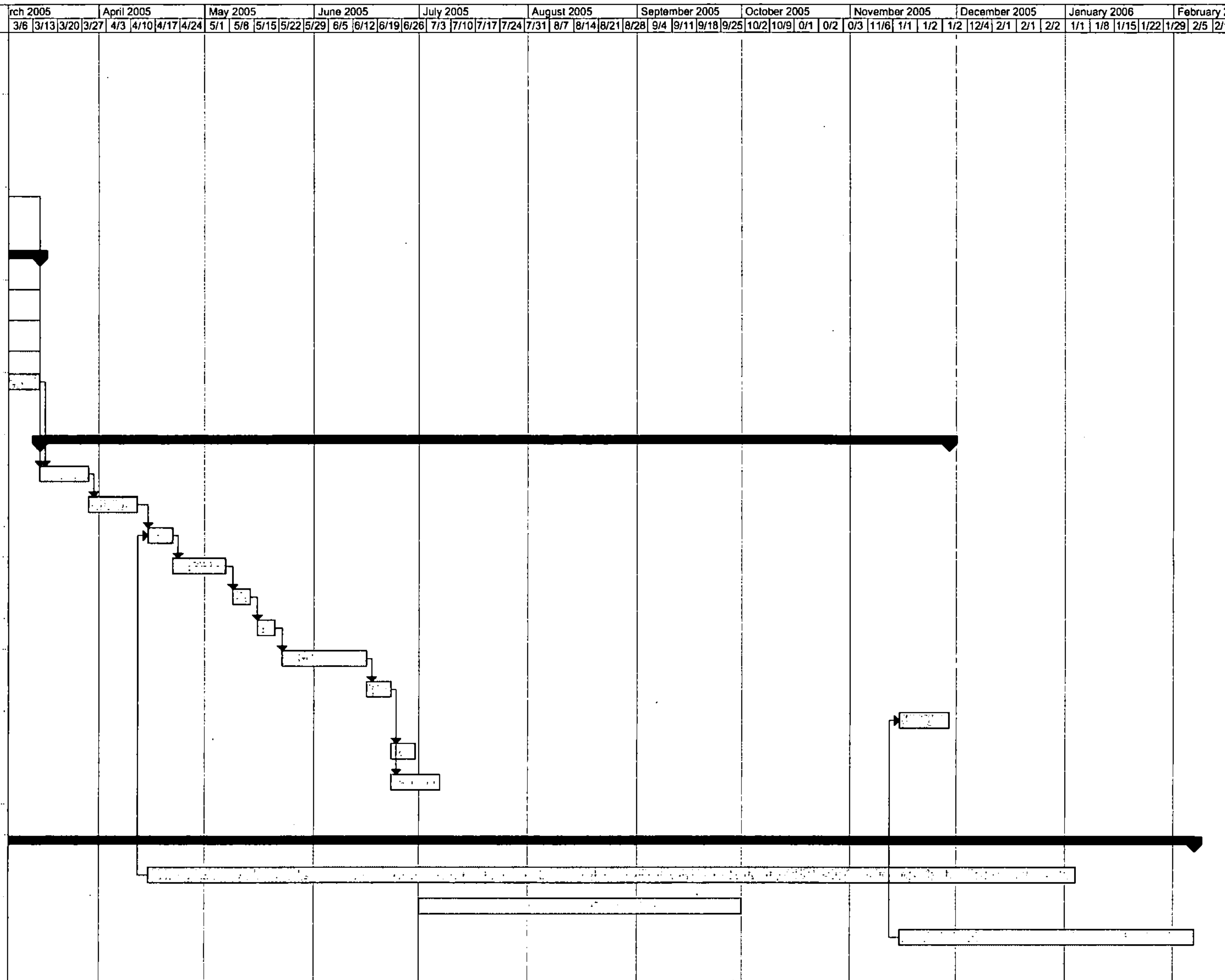
McCormick & Baxter
Schedule
Upland Evapotranspiration Cover
Design and Construction

ID		Task Name	Duration	Start	Finish
1		**Design**	**14 wks**	**Tue 6/1/04**	**Mon 9/6/04**
2		ET Cover Pre-Final Design (90%)	1.5 mons	Tue 6/1/04	Mon 7/12/04
3		ET Cover Final Design (100%)	1 mon	Tue 8/10/04	Mon 9/6/04
4					
5		**Procurement**	**14 wks**	**Tue 11/2/04**	**Mon 2/7/05**
6		ET Cover	3.5 mons	Tue 11/2/04	Mon 2/7/05
7					
8		**Preparatory Work**	**15 wks**	**Tue 11/30/04**	**Mon 3/14/05**
9		Abandon Utilities	3 wks	Tue 11/30/04	Mon 12/20/04
10		Abandon Wells	4 wks	Tue 12/21/04	Mon 1/17/05
11		Remove Structures	3 wks	Tue 1/18/05	Mon 2/7/05
12		Relocate Office	5 wks	Tue 2/8/05	Mon 3/14/05
13					
14		**ET Cover Construction**	**37 wks**	**Tue 3/15/05**	**Mon 11/28/05**
15		Mob & Prep Work	2 wks	Tue 3/15/05	Mon 3/28/05
16		Clear/Grub	2 wks	Tue 3/29/05	Mon 4/11/05
17		Level Site	1 wk	Fri 4/15/05	Thu 4/21/05
18		Prepare Subgrade/Fill Within Wall (0-.5%)	11 days	Fri 4/22/05	Fri 5/6/05
19		Amend Existing Soil	1 wk	Mon 5/9/05	Fri 5/13/05
20		Install Demarcation Layer	1 wk	Mon 5/16/05	Fri 5/20/05
21		Place 2' Topsoil	18 days	Mon 5/23/05	Wed 6/15/05
22		Seeding	1 wk	Thu 6/16/05	Wed 6/22/05
23		Plant (Delayed Until Good Plant Season)	2 wks	Tue 11/15/05	Mon 11/28/05
24		Finishing Activities	1 wk	Thu 6/23/05	Wed 6/29/05
25		Demob	2 wks	Thu 6/23/05	Wed 7/6/05
26					
27		**Outside Controls**	**62 wks**	**Tue 11/30/04**	**Mon 2/6/06**
28		Reasonable Construction Season	37.6 wks	Fri 4/15/05	Tue 1/3/06
29		Reasonably Dry Weather	13.2 wks	Fri 7/1/05	Fri 9/30/05
30		Good Planting Season	3 mons	Tue 11/15/05	Mon 2/6/06
31		Completion of Sediment Cap Work	0 wks	Tue 11/30/04	Tue 11/30/04



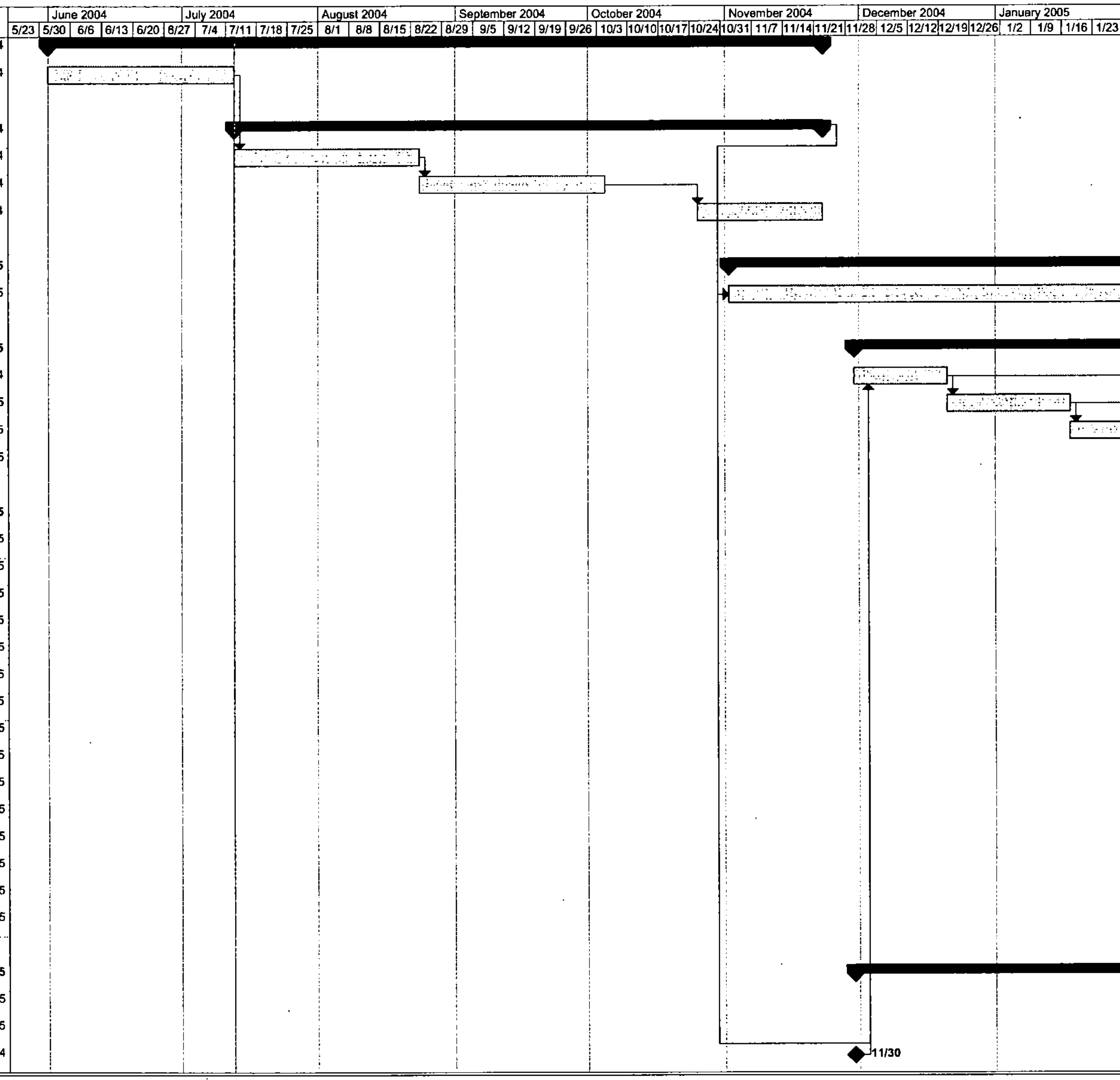
McCormick & Baxter
Schedule
Upland Evapotranspiration Cover
Design and Construction

ID	Task Name
1	**Design**
2	ET Cover Pre-Final Design (90%)
3	ET Cover Final Design (100%)
4	
5	**Procurement**
6	ET Cover
7	
8	**Preparatory Work**
9	Abandon Utilities
10	Abandon Wells
11	Remove Structures
12	Relocate Office
13	
14	**ET Cover Construction**
15	Mob & Prep Work
16	Clear/Grub
17	Level Site
18	Prepare Subgrade/Fill Within Wall (0-.5%)
19	Amend Existing Soil
20	Install Demarcation Layer
21	Place 2' Topsoil
22	Seeding
23	Plant (Delayed Until Good Plant Season)
24	Finishing Activities
25	Demob
26	
27	**Outside Controls**
28	Reasonable Construction Season
29	Reasonably Dry Weather
30	Good Planting Season
31	Completion of Sediment Cap Work



McCormick & Baxter
Schedule
Upland Impermeable Cover
Design and Construction

ID		Task Name	Duration	Start	Finish
1		**Design**	**25 wks**	**Tue 6/1/04**	**Mon 11/22/04**
2		Preparatory Work (ET Cover)	1.5 mons	Tue 6/1/04	Mon 7/12/04
3					
4		**Impermeable Cover**	**19 wks**	**Tue 7/13/04**	**Mon 11/22/04**
5		Concept Design (50%)	1.5 mons	Tue 7/13/04	Mon 8/23/04
6		Pre-Final Design (90%)	1.5 mons	Tue 8/24/04	Mon 10/4/04
7		Final Design	1 mon	Tue 10/26/04	Mon 11/22/04
8					
9		**Procurement**	**14 wks**	**Tue 11/2/04**	**Mon 2/7/05**
10		Impermeable Cover	3.5 mons	Tue 11/2/04	Mon 2/7/05
11					
12		**Preparatory Work**	**15 wks**	**Tue 11/30/04**	**Mon 3/14/05**
13		Abandon Utilities	3 wks	Tue 11/30/04	Mon 12/20/04
14		Abandon Wells	4 wks	Tue 12/21/04	Mon 1/17/05
15		Remove Structures	3 wks	Tue 1/18/05	Mon 2/7/05
16		Relocate Office	5 wks	Tue 2/8/05	Mon 3/14/05
17					
18		**Impermeable Cover Construction**	**36.6 wks**	**Tue 3/15/05**	**Thu 11/24/05**
19		Mob & Prep Work	2 wks	Tue 3/15/05	Mon 3/28/05
20		Clear/Grub	2 wks	Tue 3/29/05	Mon 4/11/05
21		Level Site	1 wk	Tue 4/12/05	Mon 4/18/05
22		Prepare Subgrade/Fill Within Wall (2%)	11 days	Tue 4/19/05	Tue 5/3/05
23		Prepare Cover Catch Basins & Piping	17 days	Wed 5/4/05	Thu 5/26/05
24		Construct Detention Basin	2 wks	Tue 4/19/05	Mon 5/2/05
25		Install Composite Liner	21 days	Fri 7/1/05	Fri 7/29/05
26		Install Drainage and Piping System	11 days	Mon 8/1/05	Mon 8/15/05
27		Install Biotic Barrier Layer	18 days	Tue 8/16/05	Thu 9/8/05
28		Install Geotextile Filter	11 days	Fri 9/9/05	Fri 9/23/05
29		Place Topsoil	13 days	Mon 9/26/05	Wed 10/12/05
30		Seeding	1 wk	Thu 10/13/05	Wed 10/19/05
31		Install Vaults & Gas Vents	16 days	Thu 10/20/05	Thu 11/10/05
32		Finishing Activities	1 wk	Fri 11/11/05	Thu 11/17/05
33		Demob	2 wks	Fri 11/11/05	Thu 11/24/05
34					
35		**Outside Controls**	**52.6 wks**	**Tue 11/30/04**	**Thu 12/1/05**
36		Reasonable Construction Season	37.6 wks	Tue 3/15/05	Thu 12/1/05
37		Reasonably Dry Weather	13.2 wks	Fri 7/1/05	Fri 9/30/05
38		Completion of Sediment Cap Work	0 wks	Tue 11/30/04	Tue 11/30/04



McCormick & Baxter
Schedule
Upland Impermeable Cover
Design and Construction

ID	Task Name
1	**Design**
2	Preparatory Work (ET Cover)
3	
4	**Impermeable Cover**
5	Concept Design (50%)
6	Pre-Final Design (90%)
7	Final Design
8	
9	**Procurement**
10	Impermeable Cover
11	
12	**Preparatory Work**
13	Abandon Utilities
14	Abandon Wells
15	Remove Structures
16	Relocate Office
17	
18	**Impermeable Cover Construction**
19	Mob & Prep Work
20	Clear/Grub
21	Level Site
22	Prepare Subgrade/Fill Within Wall (2%)
23	Prepare Cover Catch Basins & Piping
24	Construct Detention Basin
25	Install Composite Liner
26	Install Drainage and Piping System
27	Install Biotic Barrier Layer
28	Install Geotextile Filter
29	Place Topsoil
30	Seeding
31	Install Vaults & Gas Vents
32	Finishing Activities
33	Demob
34	
35	**Outside Controls**
36	Reasonable Construction Season
37	Reasonably Dry Weather
38	Completion of Sediment Cap Work

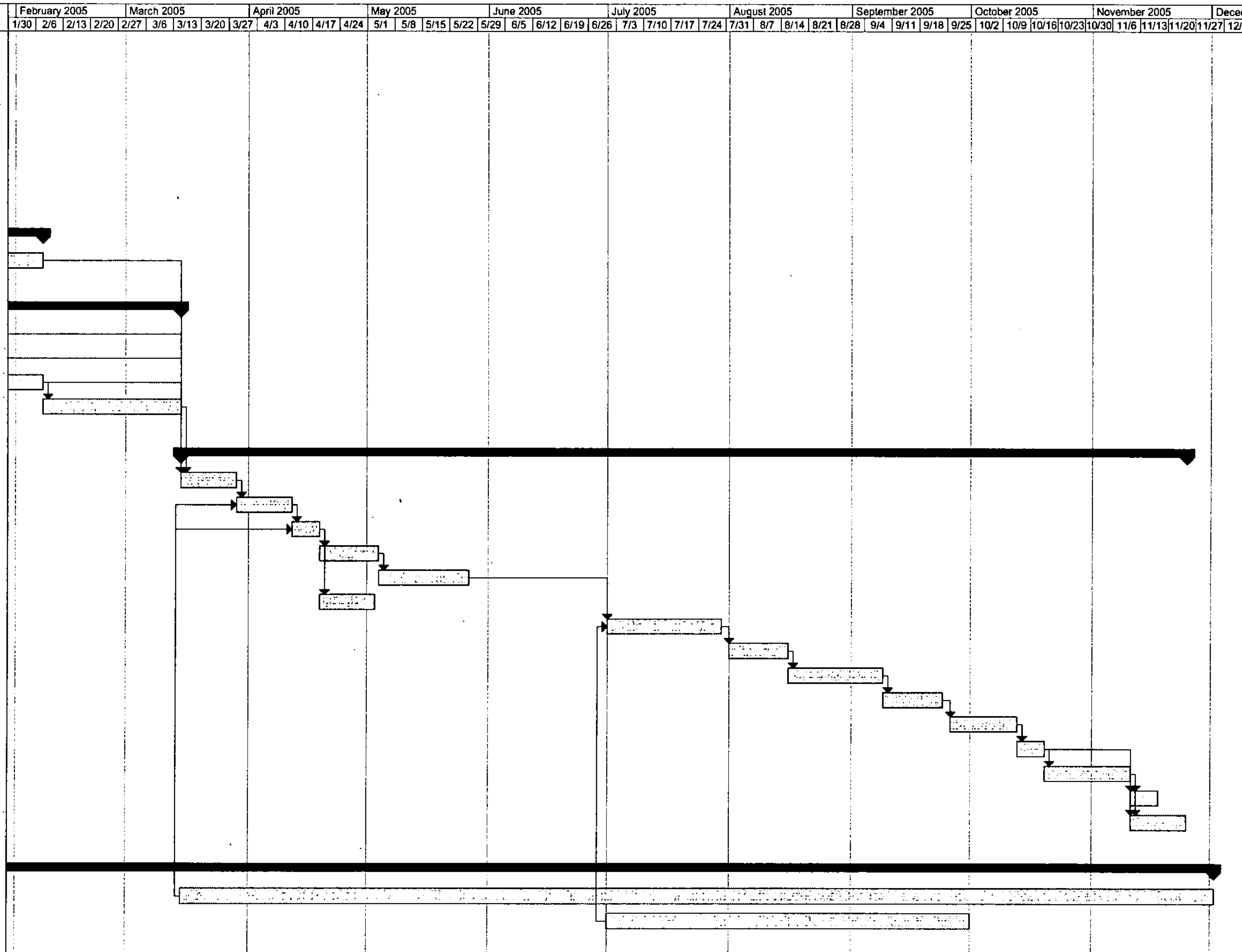


TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Monolithic ET Covers									
Marine Corps Logistics Base Superfund Site	Albany, GA	50.4 inches/ 1,280 mm	A 24-inch thick cover constructed of sandy clay mixed with compost. Vegetated with hybrid poplars and bermuda grass.	Reduce infiltration at combined MSW/ hazardous waste landfill	March 2000	UNSAT-H	Percolation predicted at 14.7 mm/year (0.58 in/yr).	Year 1 percolation was 131 mm (5.16 in). Year 2 was 3.1 mm (0.12 in), and Year 3 had approximately 220 mm (8.66 in) of percolation.	EPA Region 4
Casting Sand Landfill	Detroit, MI	31 inches/ 787.4 mm	5 acres of silty loam cover vegetated with 7,500 hybrid poplars.	Reduce infiltration at industrial waste landfill	1998	NA	NA	NA	Ecolotree, Inc.
MSW Landfill	Richmond, VA	42.5 inches/ 1,079.1 mm	10 acres of 96-inch thick sand cover vegetated with 15,000 hybrid poplars.	Reduce infiltration at MSW landfill	1995	NA	NA	NA	Ecolotree, Inc.
Electrical Power Plant	St. Louis, MO	38 inches/ 965.2 mm	A 5-acre cover constructed of sand-loam soil vegetated with 7,500 hybrid poplars.	Reduce Infiltration at fly ash landfill	1995	NA	NA	NA	Ecolotree, Inc.
Bluestem Landfill Site No. 1	Cedar Rapids, IA	34 inches/ 863.6 mm	A 3-acre cover constructed of 24 inches of cover soil vegetated with 5,600 hybrid poplars.	Reduce infiltration at MSW landfill	1994	NA	NA	NA	Ecolotree, Inc.

TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Bluestem Landfill Site No. 2	Cedar Rapids, IA	36.4 inches/ 924.6 mm	Top layer consists of 36 inches of sandy clay amended with compost. Second layer consists of 24 inches of sandy clay. Vegetated with hybrid poplar and grasses such as tall fescue.	Reduce infiltration at MSW landfill	October 2000	HELP	Percolation predicted at 13 inches/year (330 mm/yr) to 26 inches/year 660 in/yr).	Year 1 percolation was 150 mm (5.9 in) compared to 750 mm (29.5 in) preciptitation. Year 2 percolation was 30 mm (1.18 in) compared to 500 mm (19.7 in) precipitation.	Bluestem Solid Waste Agency
Center Hill Landfill	Cincinnati, OH	36.4 inches/ 924.6 mm	24 - 48 inch thick cover consisting of clayey sand, clayey sand-silty sand, lean clay, or lean-clay silt. Vegetated with 30,000 trees (cottonwood, poplars, and willows).	Assess percolation through cover (based on leachate collection) at non-hazardous waste site	May 1999	NA	NA	Leachate production flow rate for the first 2 years ranged between 50 to 300 liters per minute relative to preciptation of 1,000 mm/yr (29.37 in/yr).	EPA Region 5
Coffey County Landfill	Burlington, KS	35.4 inches/ 899.2 mm	A 7-acre cover consisting of a 6-inch layer of topsoil underlain by a 42-inch layer of silty clay. Vegetated with native grasses.	Reduce infiltration at MSW landfill	September 2003	UNSAT-H	Percolation predicted at 3 mm/yr (0.12 in/yr).	NA	Kansas Department of Health and Environment

TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Duvall Custodial Landfill	Duvall, WA	47 inches/ 1,193.8 mm	A 13-acre cover constructed of 72 inches of loam. Vegetated with 10,000 hybrid poplars.	Reduce infiltration at MSW landfill	1999	NA	NA	Deep percolation through the cover is estimated at about 2 inches for the 2001 water year, 12 inches for the 2002 water year, and 4 inches for the 2003 water year.	King County Solid Waste Division
Green II Landfill	Logan, OH	36.5 inches/ 927.1 mm	A 10-acre cover constructed of 21 inches of sandy clay vegetated with grass, shrubs, hybird poplar and willow trees.	Reduce infiltration at combined MSW/hazardous waste landfill	2000	HELP	NA	Leachate production flow rate for year 1 was 1E6 liters/yr relative to precipitation of 1,000 mm/yr (39.37 in/yr). Leachate production flow rate for Year 2 was 4E6 liters/yr relative to precipitation of 1,000 mm/yr (39.37 in/yr).	Ohio EPA
Grundy County Landfill	Grundy Center, IA	34 inches/ 863.6 mm	A 1-acre cover constructed of 48 inches of cover soil vegetated with 1,400 hybrid poplars.	Reduce infiltration at MSW landfill	1994	NA	NA	NA	Ecolotree, Inc.
Horseshoe Bend Landfill	Lawrenceberg, TN	56 inches/ 1,422.4 mm	A 2-acre cover constructed of silty sands and clayey soils vegetated with 1,400 hybrid poplars.	Reduce infiltration at industrial waste landfill	1998	NA	NA	NA	ARCADIS Geraghty & Miller

TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Industrial Excess Landfill Superfund Site	Canton, OH	36.8 inches/ 934.72 mm	Proposed 30-acre cover to be constructed of 2 to 3 feet of soil with poplars and other vegetation planted at selected areas.	Reduce infiltration at former landfill site	Proposed	HELP	Percolation predicted at 4 inches (101.6 mm) per year.	NA	EPA Region 5
Johnson County Landfill	Shwanee, KS	38 inches/ 965.2 mm	A 75-acre cover consisting of a 1-foot layer of amended clay underlain by 4.5 feet of weathered shale. Vegetated with native grasses.	Reduce infiltration at MSW landfill	Under Construction	UNSAT-H	Percolation predicted at 3 mm/yr (0.12 mm/yr).	NA	Kansas Department of Health and Environment
Lakeside Reclamation Landfill	Beaverton, OR	37 inches/ 939.8 mm	A 3-acre cover constructed of 48 inches of silt loam vegetated with 7,500 hybrid poplars.	Reduce infiltration at construction debris landfill	1990	NA	NA	Soil moisture content was less underneath the ET Cover than the grass-only cap. The ET Cover extracted more moisture from depths greater than 2 feet.	Ecolotree, Inc.

TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

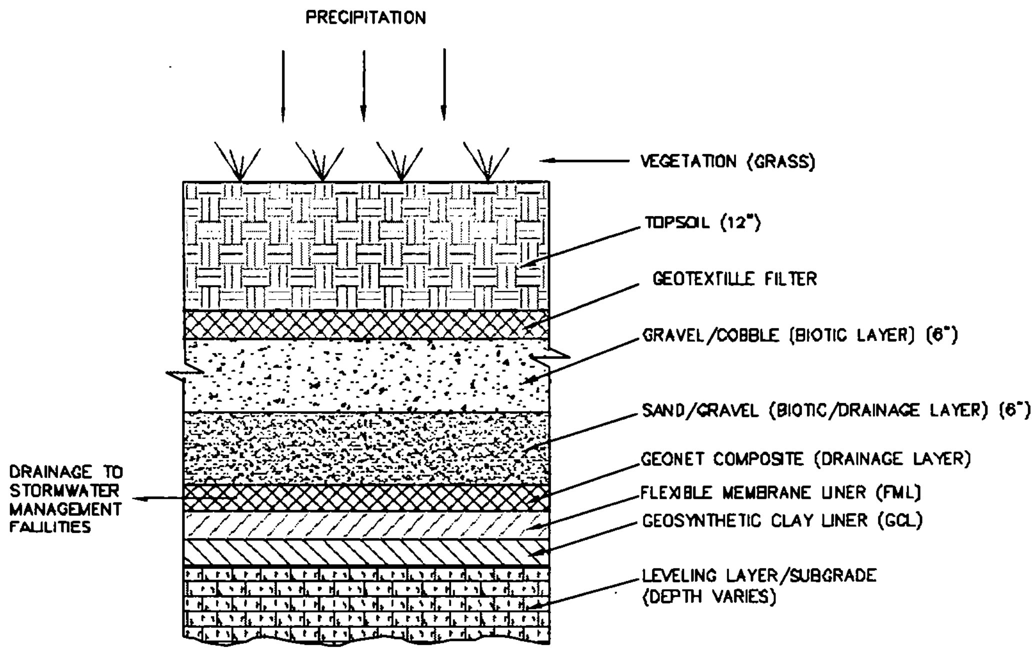
McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Naval Surface Warfare Center Superfund Site	Dahlgren, VA	39.4 inches/ 1,000.8 mm	A 3.5-acre cover consisting of a 6-inch topsoil layer underlain by an 18-inch layer of select fill material. Vegetated with hybrid poplars, red mulberry, sycamore, tulip poplar, and loblolly pine trees.	Reduce infiltration at MSW landfill	November 2000	HELP	Percolation predicted at 11.6 inches/year (294.64 mm/yr). Percolation without a cap was predicted at 16.7 inches/year (424.2 mm/yr).	NA	US Navy
Capillary Barrier ET Covers									
Omega Hills Landfill	Milwaukee, WI	31.9 inches/ 810 mm	A 1.78-acre cover consisting of the following layers from top to bottom: 5.9-inches topsoil, 11.8-inches glacial till, 11.8-inches medium uniform graded sand, and 23.6-inches compacted glacial till. Vegetated with tall fescue, creeping red fescue, and perennial ryegrass.	Reduce infiltration at hazardous waste landfill	1986	NA	NA	Mixed results. One year the cap produced more leachate than the conventional barrier. Another year it produced less leachate.	University of Wisconsin

TABLE 3-1
MONOLITHIC AND CAPILLARY BARRIER ET COVERS AT HUMID SITES AROUND THE UNITED STATES

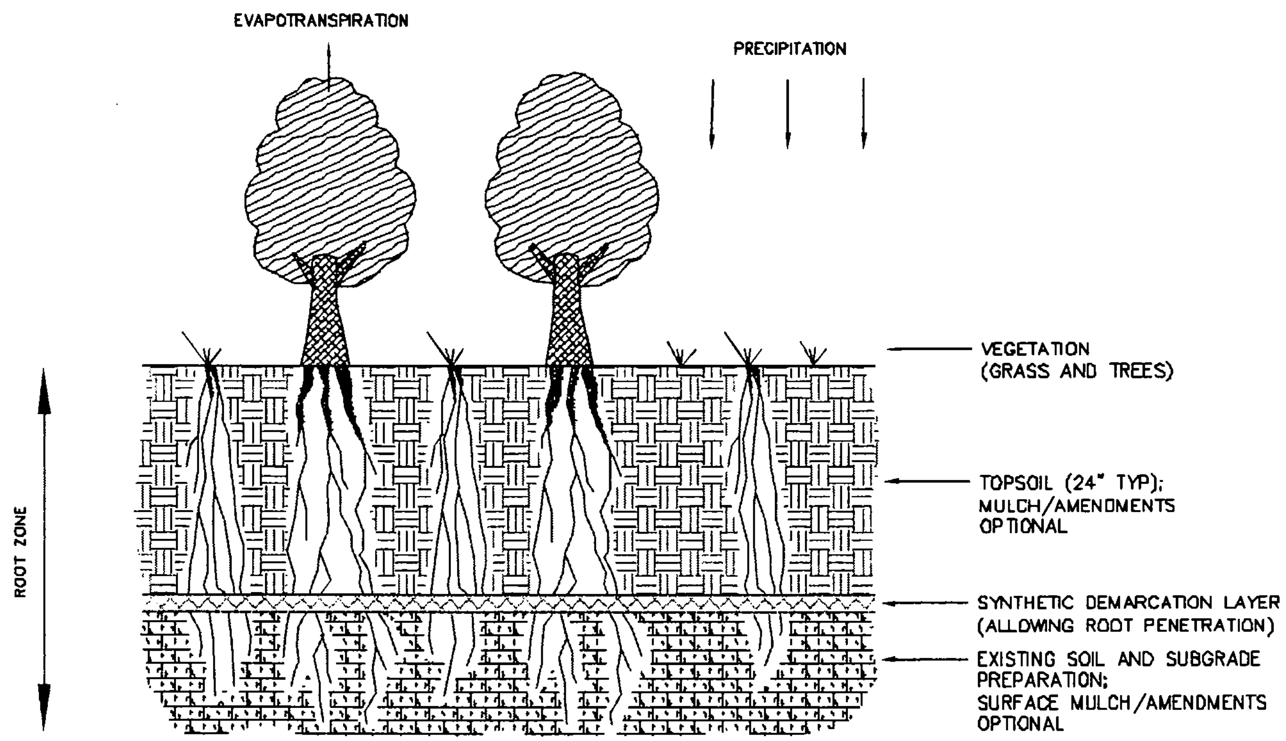
McCormick and Baxter Superfund Site
Portland, Oregon

Site Name	Location	Annual Precipitation	ET Cover Description	ET Cover Function	Date Installed	Model Used	Model Prediction	Performance Data	Contact
Sheffield Radioactive Waste Site	Sheffield, IL	37 inches/ 939.8 mm	A 2.2-acre cover consisting of the following layers from top to bottom: 5.9-inches topsoil, 23.6-inches compacted glacial till, geofabric, 23.6-inches peagravel, and 23.6 to 29.5-inches compacted glacial till. Vegetated with fescue, rye, and timothy grasses.	Reduce infiltration at radioactive waste site	1983	NA	NA	Infiltration estimated at 3 mm (0.12 in) per year.	US Nuclear Regulatory Commission



IMPERMEABLE COVER SECTION (TYPICAL)

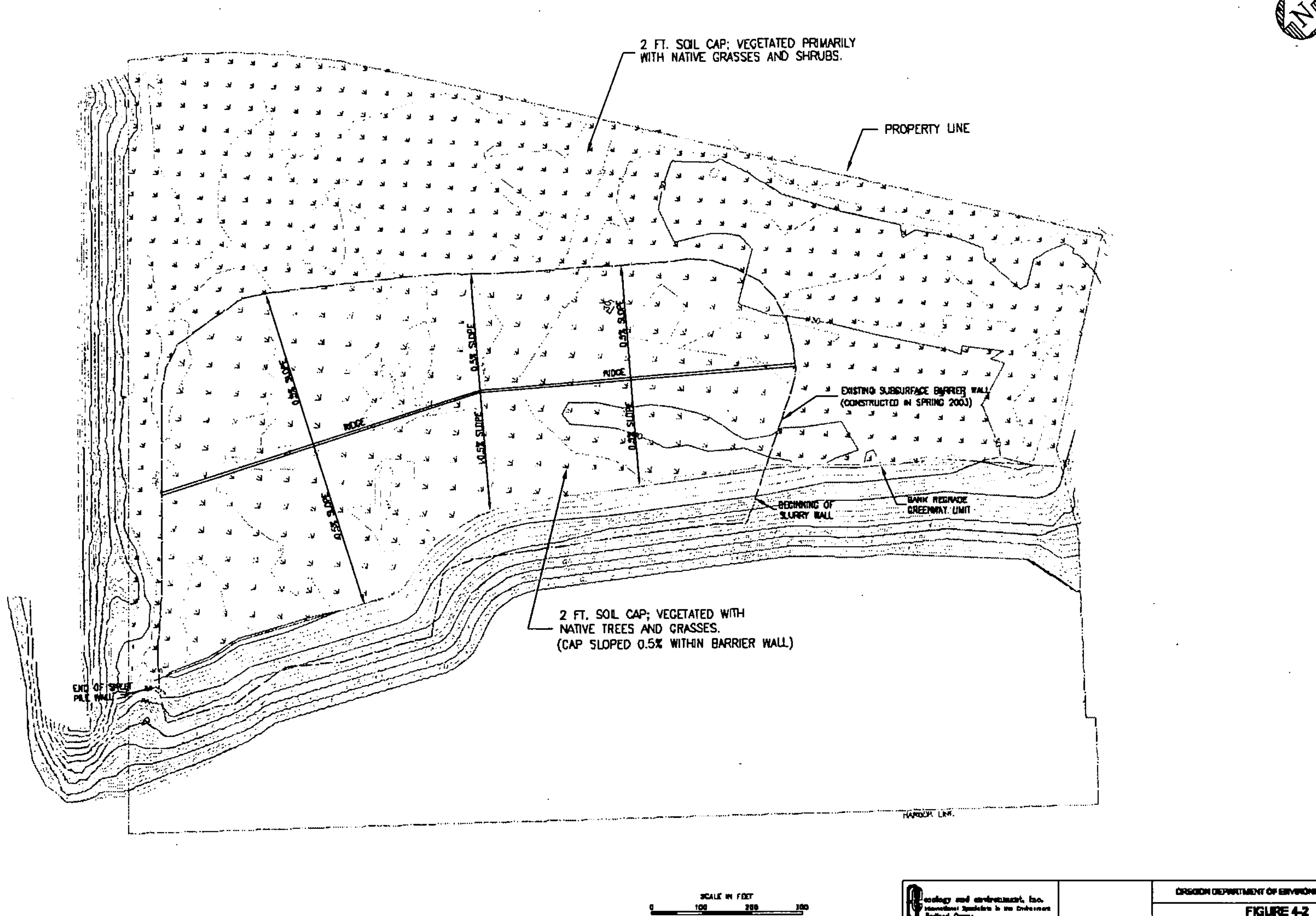
NOT TO SCALE



ET COVER SECTION (TYPICAL)

NOT TO SCALE

ecology and environment, inc. International Specialists in the Environment Portland, Oregon	OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY		
DESIGNED BY: C. NANCARROW	FIGURE 4-1 TYPICAL COVER SECTIONS ET COVER TECHNICAL MEMORANDUM		
CHECKED BY: A. WHITMAN			
DRAWN BY: S.STEVENS	SCALE NONE	DATE ISSUED 8/28/04	CAD FILE NO. CAP DETAILS.DWG



ecology and environment, inc.
International Specialists in the Environment
Portland, Oregon

CHECKED BY

DRAWN BY: S.STEVENS

A. WHITMAN

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

FIGURE 4-2
CONCEPTUAL PLAN:
EVAPOTRANSPIRATION COVER

NOTED | 6-18-04

FIGURES

APPENDIX A

Ecolotree Design Report

50% DESIGN REPORT

FOR

AN EVAPOTRANSPIRATION COVER

AT

THE MCCORMICK AND BAXTER CREOSOTING COMPANY SUPERFUND SITE, PORTLAND, OREGON

ECOLOTREE PROJECT #2004.13

July 2004

ecolotree®

3017 Valley View Ln
North Liberty, Iowa 52317
Phone (319) 665-3547
Fax (319) 665-8035
www.ecolotree.com
Email: info@ecolotree.com

50% Design Report for an Evapotranspiration Cover at the McCormick and Baxter Superfund Site, Portland, Oregon

Contents

Tables

Figures

1. Introduction

1.1 Purpose and Scope

This 50% design report has been prepared to provide information to the Oregon Department of Environmental Quality (ODEQ) with regards to the potential of evapotranspiration (ET) covers/caps at the McCormick and Baxter Creosoting Company Superfund Site, Portland, Oregon (site). The report summarizes the site inspection results, evaluates the soil and amendment options available for constructing the cover, provides hydrologic modeling results for 14 cover design scenarios, and provides 50% design details and recommendations for two evapotranspiration (ET) cover designs. One ET cover design utilizes hybrid poplar trees and understory grasses ("ECap™"), while a second ET cover design utilizes a blend of hybrid poplar trees, other deciduous trees, and conifers (evergreens) with a grass understory ("mixed species ECap™").

In Appendix A, biosolids are also further defined as a possible amendment to the existing sandy site soils. On an ECap™ landfill cover in the Seattle area, biosolids stimulated approximately 400% faster biomass growth by improving plant nutrition and soil structure. Biosolids are currently produced within approximately six miles of the McCormick and Baxter site. In 2002, City of Portland biosolids were land applied onto dry land pasture in eastern Oregon. The program summary and plant response to this biosolid application is provided in the Appendix.

2. Site Inspection Activities and Results

2.1 McCormick and Baxter Site Inspection

A site inspection/pre-design meeting was held at the McCormick and Baxter facility on April 5, 2004, with staff from ODEQ (Kevin Parrett), Ecology and Environment (E&E) (Chad Nancarrow), and Ecolotree (Louis Licht) in attendance. The following tasks were completed:

- Visually inspected the site and documented site conditions with digital photography
- Reviewed site drawings and identified the location of previous wood treatment operations, waste disposal areas, and monitoring wells
- Reviewed historic activities at the site, including completed site cleanup activities
- Reviewed existing site data, including depth to groundwater and groundwater monitoring well concentrations
- Reviewed existing vegetation at the site. Currently the site has a sparse grass cover, with grass roots typically extending to an 8-10 inch depth below ground
- Collected two samples of surficial soils at the site for texture and agronomic analysis
- Verified the potential planting area dimensions

- Evaluated a potential topsoil source in St. Helens, Oregon and took samples for texture and agronomic analysis (Figure 1)

2.2 Riverbend Landfill Inspection

A site inspection was conducted at the Riverbend Landfill in McMinnville, Oregon on April 7, 2004, with staff from ODEQ (Kevin Parrett), E&E (Chad Nancarrow), Ecolotree (Louis Licht), and Waste Management, Inc. (George Duvendek) in attendance. The following observations were made:

- A 15 acre hybrid poplar tree treatment system ("EBuffer®") was utilized at the site between 1992 and 2003 to treat between 7-12 million gallons/year (17-29 inches) of irrigated landfill leachate

- Due to landfill expansion, the 15 acre system has been replaced with a 45 acre hybrid poplar plantation

- Nitrogen loading and water application rates are the primary regulated parameters

- Leachate is collected, stored in an open lagoon, mechanically filtered, and then irrigated via drip tubing

- The drip irrigated leachate has little drift and effectively percolates into the soil

- Herbicide application onto a 3 foot wide zone along the tree rows has effectively reduced weed and grass competition

- Four varieties of hybrid poplars were planted in zones of several acres each, with each zone irrigated separately

- In general the trees appear healthy. One poplar variety has grown less vigorously, apparently due to less tolerance for the soluble salt levels in the irrigated leachate (this variety is being replaced).

- The ODEQ solid waste division permits and monitors this site

2.3 Woodburn WWTP Inspection

A site inspection was conducted at the Woodburn Wastewater Treatment Plant (WWTP) in Woodburn, Oregon on April 7, 2004, with staff from ODEQ (Kevin Parrett), E&E (Chad Nancarrow), Ecolotree (Louis Licht), and the City of Woodburn (Frank Sinclair) in attendance. The following observations were made:

- A hybrid poplar tree plantation has been utilized at the site since 1995 for tertiary treatment of municipal wastewater

- The project began with a 10 acre demonstration, and currently encompasses 130 acres
- Four varieties of hybrid poplar were planted in distinct zones, with spacing of 13 feet between rows and seven feet between trees within a row
- Approximately 900,000 gallons of wastewater are irrigated each day during the growing season by spray irrigation onto the trees
- The primary objective of the plantation is to reduce the temperature of the wastewater prior to migration into the Pudding River
- A secondary objective of the plantation is to treat nitrogen applied by the addition of wastewater treatment biosolids
- Herbicide application onto a 3 foot wide zone along the tree rows has effectively reduced weed and grass competition
- The ODEQ wastewater division permits and monitors this site

2.4 Duvall Landfill Inspection

A site inspection was conducted at the Duvall Landfill in Redmond, Washington on April 8, 2004, with staff from ODEQ (Kevin Parrett), E&E (Chad Nancarrow), Ecolotree (Louis Licht), and King County Solid Waste (Anne Holmes) in attendance. The following observations were made (Figures 2-4):

- The landfill is 13 acres in size, with a pre-Subtitle D soil cover placed over it in 1976
- 10,000 hybrid poplar trees were planted in April 2000 using the ECap™ technique
- Four varieties of hybrid poplar were planted in zones of eight rows each
- A spray irrigation system was utilized to help establish the trees and to prevent drought pressure during the 2000 and 2001 summer months. Though the system is still functional, irrigation has not been used since.
- Tree growth rates at the site are variable, due to differences in tree variety, degree of soil compaction, and soil fertility. For areas where poor soil fertility has been corrected by fertilizer and biosolid addition, the trees are over 25 feet tall. Excessive soil compaction continues to reduce growth rates in one portion of the site.
- Mountain voles have damaged roots and bark on trees around the perimeter of the site (closest to the mature forest surrounding the site). The voles specifically damaged poplar variety 184-411. Biosolids greatly reduced vole predation in the year of application.

- To encourage the transition from fast growing pioneering trees to slower growing climax tree species, interplanting the poplar with western red cedar is planned

- Based on soil moisture monitoring data, the late fall available water holding capacity (AWHC) has increased by > 200,000 gallons/acre for the effective root zone (0-6 feet below ground). This increase in AWHC allows for significantly more storage of winter rainfall and thus reduced water percolation into waste.

2.5 Washington State University Tree Farm Inspection

A site inspection was conducted at the Washington State University tree farm in Puyallup, Washington on April 8, 2004, with staff from ODEQ (Kevin Parrett), E&E (Chad Nancarrow), and Ecolotree (Louis Licht) in attendance. The following observations were made:

- Since the site is in a flood plain with a river on the farm edge, the trees can access groundwater as their root systems develop

- The site was planted approximately 25 year ago to test numerous varieties of new poplar clones

- One plot consists of interplanted hybrid poplar and western red cedar (Figure 5). This plot reveals that it is feasible to interplant poplar with conifers.

- The poplars exceed 20 inches in diameter at breast height (DBH) and 90 feet in height. The cedars have DBH > 10 inches and stand over 30 feet tall.

2.6 Presentations

Presentations were made by Ecolotree staff to ODEQ staff in Portland on April 6 and to USEPA Region 10 staff in Seattle on April 7, 2004. Topics specifically related to the McCormick and Baxter site were discussed, including a detailed explanation of ECap™ cover system function and recent research results by the University of Iowa Department of Civil/Environmental Engineering documenting mineralization of polyaromatic hydrocarbons (PAHs) in the root zone of plants.

3. Soil and Amendment Agronomic Testing Results

3.1 Soil Agronomic Testing Results

Two soil samples were taken by Ecolotree staff on April 5, 2004 from onsite near surface soil ("sediment" or "existing cover") at the site, and two samples were taken of a potential topsoil borrow source in St. Helens, Oregon. The samples were analyzed by A&L Heartland Laboratories, Inc. (Atlantic, Iowa) for texture, pH, salts, nutrients, and other agronomic parameters (results provided as Table 1).

On May 17, 2004, two additional soil samples were taken of the existing cover, and three additional soil samples were taken of the St. Helens topsoil source. These five samples were tested for grain size distribution (percent sand, silt, and clay).

The results and recommendations are summarized as follows:

1. Texture: The soil texture was classified (USDA classification) as:
   - Existing cover = sand for three samples and sandy loam for one sample
   - St. Helens topsoil = sandy loam for three samples and loam for two samples

   Although sand and sandy loam textures typically have low water holding capacity and low fertility, their coarse structure can allow for deep (> 10 feet) root systems. To improve water-holding capacity, the soils would benefit from the addition of an organic amendment.

2. pH: Soil pH was sufficient for the onsite soils, but low (< 5.8) for the two topsoil samples. Lime addition to the topsoil is recommended to increase the pH to 6.0.

3. Organic matter: The soil organic matter was low (< 2%) for three of the four samples, ranging between 1.4 and 1.6%. These low levels are typical of coarse-textured soils. Addition of an organic amendment at a ratio of approximately 5% by soil volume is recommended. One of the onsite soils had a very high organic matter of 6.3%; this result is considered either an anomaly or due to laboratory error.

4. Soluble salts: The concentration of soluble salts was low for both samples tested (one onsite soil sample, one topsoil sample), which was expected given their coarse texture and thus inability to retain salts. The low concentrations are not by themselves considered detrimental to tree health, but they do suggest that fertilizer addition will be necessary to provide sufficient nutrients.

5. Cation exchange capacity. The CEC, which is a measure of the ability of a soil to retain positively charged nutrients such as phosphorus and magnesium, was sufficient for all four samples.

6. Macronutrients: The onsite soil samples were deficient in phosphorus, while one of the onsite samples was deficient in both potassium and sulfur. The topsoil samples had sufficient concentrations of all macronutrients tested. Magnesium was very high for one of the onsite soil samples, but is not considered detrimental to tree health. Addition of approximately 80 lbs/acre/year of P_2O_5 and 80 lbs/acre/year of K_2O by granular fertilizer addition is recommended to encourage tree and grass growth.

   Although the samples were not tested for nitrogen (rapid speciation of soil nitrogen between nitrate, nitrite, ammonia, ammonium, and nitrogen gas makes nitrogen testing of little value), the coarse texture and low salt content of the soils suggest that the soils are likely deficient in nitrogen. Addition of approximately 150 lbs of N/acre/year by granular fertilizer addition is recommended to encourage tree and grass growth.

7. Micronutrients: Iron was high for all four samples, but is not considered detrimental to tree health. Although copper and zinc were both low for three of the four samples (likely due to the sandy soils and high amounts of precipitation flushing out these cations), deficiencies in plants are rare for soil pH < 7.0. Addition of an organic amendment to the soil would also help to augment for these micronutrients.

3.2 Amendment Agronomic Testing Results

Due to the sandy onsite soils and sandy borrow soil options, an organic amendment is recommended for blending with these soils for the following reasons:

- Increase the soil organic matter content
- Improve the soil available water holding capacity (e.g. improve the soil "sponge")
- Provide beneficial microorganisms
- Bind or sorb organic compounds such as pesticides, thus lessening their tendency to leach into water supplies
- Provide a long term, slow-release supply of nutrients
- Improve the soil structure
- Stabilize soil and reduce erosion by binding soil particles together
- When placed on the surface as a tree mulch, BioGro composted class 1 biosolids from the City of Seattle reduced root damage from mountain voles

Numerous horticulture and agriculture sites, as well as the Woodburn and Duvall sites discussed in Section 2, have demonstrated the effectiveness of composted municipal wastewater treatment plant biosolids. Although composted biosolids are not considered a high-grade fertilizer, they do contain the plant nutrients nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, manganese, iron, copper, zinc, and molybdenum. Thus, to maximize plant growth rates both composted biosolids and granular fertilizer are recommended for the site.

The City of Portland, Oregon was identified as a local provider of commercially available biosolids. Appendix A details information about these biosolids, including the nutrient analyses, measured improvement in soil agronomic properties, and measured improvement to plant mass growth. Plant biomass growth improved by over six times compared to soils not amended with biosolids (2,208 lbs/acre on the amended site versus 353 lbs/acre on the non-amended site).

4. Numerical Modeling

4.1 Introduction

Hydrologic numerical models are useful tools for evaluating prescriptive cover and alternative cover performance, and as such have been utilized for numerous sites over the past 10 years. The primary objective of modeling is typically to predict infiltration (i.e. percolation) through various cover design options. Although the ability of models to accurately predict *absolute* infiltration rates is questionable, models do allow the user to evaluate the impact of changing design features (e.g. change the soil type, cover thickness, vegetation properties) on *relative* infiltration rates (ITRC, 2003).

4.2 Justification for the Selected Model

The HYDRUS-1D model ("HYDRUS", Version 2.0, Simunek et al., 1998) was used to evaluate infiltration through 14 ET cover design options. HYDRUS is recommended by modeling experts (ITRC, 2003; Ankeny and Benson, 2001) for landfill cover design evaluation. This model provides rigorous methods of evaluating saturated and unsaturated water, root water uptake, and evaporation. HYDRUS uses the Richards' equation to calculate saturated and unsaturated water flow. Detailed information about the model is available at the following web site: http://www.ussl.ars.usda.gov/models/hydrus2d.htm.

The HELP model was not utilized because it is generally no longer recommended by modeling experts for cover design evaluation, as it is a physically incorrect model that does not allow for sensitivity analysis (ITRC, 2003).

4.3 Model Inputs and Assumptions

4.3.1 Climatic Conditions

Historical climatic data was reviewed for the site to determine an appropriate time period to perform infiltration modeling. Due to the availability of PET data between 1992-2003, this time period was selected. Precipitation data for the Portland airport was obtained from the Western Regional Climate Center (Reno, Nevada). The average annual precipitation between 1992-2003 was 38.3 inches, ranging between 29.5 inches in 1992 and 63.2 inches in 1996.

Grass and poplar tree potential evapotranspiration (PET) data was obtained from the Pacific Northwest Cooperative Agricultural Weather Network (AgriMet, www.usbr.gov/pn/agrimet) for Forest Grove, Oregon (the closest weather station to Portland with > 5 years of historic data). Average annual grass PET between 1992-2003 was 28.0 inches, while poplar PET was adjusted using a crop coefficient factor (Section 4.3.3, Plant Properties).

4.3.2 Soil Properties

Soil properties that govern water movement were estimated by HYDRUS using laboratory testing results of soil grain size distributions. The testing results indicated that existing cover soil ("sediment") is sand, while the St. Helens, Oregon topsoil source is a loam/sandy loam. It was assumed that by adding 5% composted biosolids (by volume) to existing cover soil, the new soil blend would have properties similar to loam.

4.3.3 Plant Properties

The PET rates used for the grass covers assumes > 90% ground coverage, while the PET rates used for the hybrid poplar, deciduous, and conifer forest covers assumes that these covers are near or at full leaf canopy (expected to take approximately 6-7 years for hybrid poplar, 12-15 years for native deciduous trees, and > 20 years for conifer).

For the hybrid poplar cover, a maximum multiplier or "crop coefficient" (K_c) of 1.25 or 1.5 times grass PET was utilized for May-August, with lower multipliers ranging between 1.05 and 1.15 for April, September, and early October to approximate leaf development and gradual tree senescence (leaf drop/dormancy). The K_c estimates are based on several references:

- K_c values for large trees in California (1.15-1.20) (Stewart et al., 1990)
- K_c values for densely planted trees in other parts of the country (1.3-1.6) (Stewart et al., 1990)
- Food and Agriculture Organization (FAO) experience with trees in combination with cover crops, indicating a rate of water use 20-30% greater than clean-cultivated orchards (FAO, 1977)
- Data relating orchard ET to the percent of ground shaded by trees, indicating that full ET will occur at 50% of ground shade (Stewart et al., 1990)

A crop coefficient of 1.0 (equal to grass) was assumed for the deciduous forest cover and the conifer forest cover (FAO, 1977).

Although the Western Regional Climate Center provides PET data for a theoretical alfalfa crop for all 12 months, it does not provide grass or poplar PET data for the dormant winter months (typically between mid February and mid October). Thus, grass PET (both for existing grasses at the site and proposed native grasses) during the winter months was assumed to be equivalent to alfalfa PET during this time period.

Alfalfa winter PET data was not utilized for modeling the tree covers, however, because this data does not take into account the significant canopy interception potential of trees. Rather, assumptions were made regarding canopy interception and subsequent evaporation of this water from the canopy. For a conifer forest, it was assumed that 30% of daily precipitation between November-February was intercepted and evaporated from canopy. A canopy interception and evaporation value of 15% was assumed for a mixed species deciduous forest for December-January, while a value of 12% was assumed for a hybrid poplar forest for December-January (the columnar branch structure of poplar makes it less effective at interception). These canopy interception values are supported by Dobson and Moffat (1993), Maidment (1993), and Moffat and McNeill (1994).

Rooting depths were typically assumed to be 0.8 feet for the existing grasses at the site, seven feet for native grasses, eight feet for hybrid poplar trees, five feet for native deciduous trees, and six feet for conifer trees. These rooting depths are supported by values reported by Dobson and Moffat (1993) and Moffat and McNeill (1994). For several of the model runs, rooting depth was decreased below these predicted depths to evaluate the impact of a more shallow root zone on infiltration. Rooting density was assumed to decrease with depth at relative ratios similar to those observed at Alternative Cover Assessment Program (ACAP) field sites (unpublished data, Albright, 2004).

4.4 Results

A total of 14 ET cover design options were evaluated using HYDRUS, with three grass-only designs, four hybrid poplar forest designs (Figure 6), four native deciduous forest designs, and three conifer forest designs (Table 2, Figure 7). The variables evaluated for sensitivity analysis were rooting depth, crop coefficient, and soil augmentation with biosolids.

The results provided in Table 2 and Figure 6 assume that either a > 90% coverage grass cover or a mature tree cover near or at full leaf canopy (the leaves or needles from one tree touching the neighboring trees) has established. Although a > 90% coverage grass cover can be obtained in 1-2 years, a significantly longer time period (5 year - 25 years, depending upon tree species) is required for a mature tree cover to develop (see Section 4.3.3). To account for this time consideration, Table 3 provides area-weighted estimates of infiltration through the cover design options at three points in time – at year 5, year 12, and year 25 following planting.

Figure 8 compares cumulative precipitation to cumulative infiltration for a grass-only design, a hybrid poplar forest design, and a conifer design.

The modeling results are summarized as follows:

1. All of the ET cover options infiltrated a significant quantity of water, ranging between 11.4 inches/year for a mature conifer forest to 26.6 inches/year for existing conditions (shallow-rooted grasses).

2. Rooting depth had minimal impact on infiltration rates. Greater root depths reduced infiltration rates by < 0.5 inches per foot of root depth. This result is due to the sandy site soils, which have very low water holding capacity and very high conductivities. For soils that are not as sandy as the site soils, greater rooting depth typically significantly reduces infiltration rates.

3. An increase in the growing season PET potential of an ET cover (higher crop coefficient) had minimal impact on infiltration rates. This result is due to the fact that little precipitation falls during the summer months, which results in substantial unused PET capacity.

4. Incorporation of biosolids into the top two feet of sandy site soils had a significant impact, reducing infiltration by approximately 1.7 inches/year (46,000 gallons/acre/year).

5. Canopy interception potential of winter precipitation had the greatest impact on infiltration rates, and is the primary reason why a mature conifer forest is predicted to outperform the other ET cover options.

5. Recommendations

Based on a review of site conditions, the site inspection, evaluation of soils data, modeling results, and results from completed projects, the following recommendations are made:

1. <u>Install a mixed species ET cover/cap that consists of 50% hybrid poplar, 25% native deciduous trees, and 25% conifer trees, utilizing the design layout provided in Figures 8-9</u>.

This cover design best utilizes the benefits of each group of trees, while minimizing their individual weaknesses:

- Poplar benefits include their rapid growth rates (will become a mature forest quickly, typically 5-7 years), deep rooting, and proven performance at similar sites in the Pacific Northwest. Their primary weakness is poor winter performance due to lower expected canopy interception rates.

- Native deciduous tree benefits include biodiversity and creation of wildlife habitat. Their weaknesses are slower growth rates, more shallow rooting expected, and only moderate winter canopy interception ability.

- The primary benefit of conifers is their superior winter performance due to higher canopy interception rates. Their main weakness is their slow growth rates, which requires a long period of time (> 10-15 years) before they develop sufficiently large canopies. Conifers can be placed on the planting edge and in the interior under deciduous trees during the establishment phase. Poplar trees would be removed as the conifers increase in size and canopy.

2. Interplant poplar, native deciduous trees, and conifers by alternating the tree rows (Figures 8-9).

3. Plant a diverse blend of warm season native grasses, cool season native grasses, legumes, and forbs (wildflowers) between the tree rows.

4. Blend an organic amendment such as composted biosolids (Appendix A) into the top two feet of existing soil at the site at a ratio of approximately 5% by volume.

5. Place two feet of the St. Helens, Oregon topsoil source over the existing site soils.

6. Install an irrigation system to minimize drought stress and to maximize grass and tree establishment and growth rates.

6. References

Ankeny, M. and Benson, C. (2001). *Designing and implementing alternative earthen final covers for waste containment facilities.* Department of Engineering Professional Development, University of Wisconsin-Madison.

Albright, W.H. (2004 - unpublished). Unpublished data regarding grass root densities observed with depth at Alternative Cover Assessment Program field sites.

Dobson, M.C. and Moffat, A.J. (1993). The potential for woodland establishment on landfill sites, Department of the Environment, England.

FAO (1977). Guidelines for predicting crop water requirements: FAO irrigation and drainage paper No. 24. Food and Agriculture Organization of the United Nations, Rome.

Interstate Technology Regulatory Council (ITRC) Alternative Landfill Technologies Team (2003). *Technical and regulatory guidance for design, installation, and monitoring of alternative final landfill covers.*

Maidment, D. (1993). *Handbook of hydrology*, New York.

Moffat, A.J. and McNeill, J. (1994). Reclaiming disturbed land for forestry. The Forest Commission Bulletin #110, England.

Simunek, J., Sejna, M, and van Genuchten, M. Th. (1998). The HYDRUS-1D software package for simulating the movement of water, heat, and multiple solutes in variable saturated media, version 2.0, U.S. Salinity Laboratory, USDA, ARS, Riverside, California.

Stewart, B.A. and Nelson, D.R. (1990). Irrigation of agricultural crops. Agronomy No. 30. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, Madison, Wisconsin.

Table 1. Soil agronomic and nutrient properties

Site:	McCormick and Baxter			Legend:	
Location:	Portland, Oregon			**Bold** = very low/low	
Sampling date:	April 5, 2004			*Italic* = very high	
Sampled by:	Louis Licht, Ecolotree			Normal = sufficient	
Sample ID		1	2	3	4
Sample description		Existing cover ("sediment")	Existing cover ("sediment")	Potential topsoil source in St. Helens, OR	Potential topsoil source in St. Helens, OR
Agronomic properties:					
Texture	N/A	Sandy loam	Sand	Sandy loam	Sandy loam
Soil pH	N/A	6.4	5.9	**5.2**	**5.7**
Organic matter	%	**1.6**	*6.3*	**1.4**	**1.5**
Soluble salts	dS/m	**0.01**		**0.01**	
Cation exchange capacity	meq/100 g	11	12	9	8
Essential macronutrients:					
Phosphorus	mg/kg	**13**	**5**	32	17
Potassium	mg/kg	115	**86**	140	147
Magnesium	mg/kg	*234*	161	143	173
Sulfur	mg/kg	7	**4**	5	10
Calcium	mg/kg	1,705	2,032	978	1,086
Essential micronutrients:					
Iron	mg/kg	*100*	*52*	*95*	*84*
Manganese	mg/kg	14	13	11	10
Boron	mg/kg	1.0	0.7	0.7	0.8
Copper	mg/kg	*6.8*	**0.5**	**0.3**	**0.3**
Zinc	mg/kg	3.7	**0.3**	**0.3**	**0.4**

Table 2. HYDRUS model run descriptions and average annual water balance results for 1992-2003

Run #	Type of vegetation	Assumed rooting depth, feet	Crop coeffcient (relative to grass), Kc	Biosolids blended into top 2 feet of existing cover	2 feet of topsoil applied	Precipitation	Runoff	Transpiration	Evaporation	Infiltration
McB 1	Existing grass	0.8	1			38.30	0.00	7.23	4.45	26.60
McB 2	Native grass mix	7	1		X	38.30	0.00	13.11	5.29	19.61
McB 3	Native grass mix	7	1	X	X	38.30	0.00	14.80	5.39	17.84
McB 4	Hybrid poplar forest	8	1.25		X	38.30	0.00	13.50	6.05	18.45
McB 5	Hybrid poplar forest	8	1.5		X	38.30	0.00	13.63	6.15	18.23
McB 6	Hybrid poplar forest	8	1.5	X	X	38.30	0.00	15.37	6.26	16.52
McB 7	Hybrid poplar forest	4	1.5	X	X	38.30	0.00	14.41	6.12	17.50
McB 8	Deciduous forest	5	1		X	38.30	0.00	12.75	7.38	17.92
McB 9	Deciduous forest	5	1	X	X	38.30	0.00	14.40	7.48	16.21
McB 10	Deciduous forest	6	1	X	X	38.30	0.00	14.62	7.52	15.98
McB 11	Deciduous forest	7	1	X	X	38.30	0.00	14.80	7.53	15.82
McB 12	Conifer forest	6	1		X	38.30	0.00	12.77	12.37	13.09
McB 13	Conifer forest	6	1	X	X	38.30	0.00	14.48	12.47	11.42
McB 14	Conifer forest	5	1	X	X	38.30	0.00	13.97	12.36	11.95

Table 3. Weighted infiltration results for cover design options after 5, 12, and 25 years (using average annual infiltration values for 1992-2003)

Cover description	After 5 years	After 12 years	After 25 years	% existing grass	% native grass	% hybrid poplar	% deciduous	% conifer	Infiltration (area-weighted average), inches
Existing grass cover	X			100%					26.60
Existing grass cover		X		100%					26.60
Existing grass cover			X	100%					26.60
Native grass cover	X				100%				17.84
Native grass cover		X			100%				17.84
Native grass cover			X		100%				17.84
Hybrid poplar forest	X				20%	80%			16.78
Hybrid poplar forest		X				100%			16.52
Hybrid poplar forest			X			100%			16.52
Native deciduous forest	X				50%		50%		17.03
Native deciduous forest		X			20%		80%		16.54
Native deciduous forest			X				100%		16.21
Conifer forest	X				80%			20%	16.56
Conifer forest		X			60%			40%	15.27
Conifer forest			X		25%			75%	13.03
Mixed hybrid poplar & deciduous forest	X				25%	50%	25%		16.77
Mixed hybrid poplar & deciduous forest		X				50%	50%		16.37
Mixed hybrid poplar & deciduous forest			X			50%	50%		16.37
Mixed hybrid poplar & conifer forest	X				40%	40%		20%	16.03
Mixed hybrid poplar & conifer forest		X			10%	50%		40%	14.61
Mixed hybrid poplar & conifer forest			X			50%		50%	13.97
Mixed deciduous & conifer forest	X				60%		20%	20%	16.23
Mixed deciduous & conifer forest		X			20%	40%		40%	14.74
Mixed deciduous & conifer forest			X				50%	50%	13.82

Figure 1. A potential topsoil source available from St. Helens, Oregon

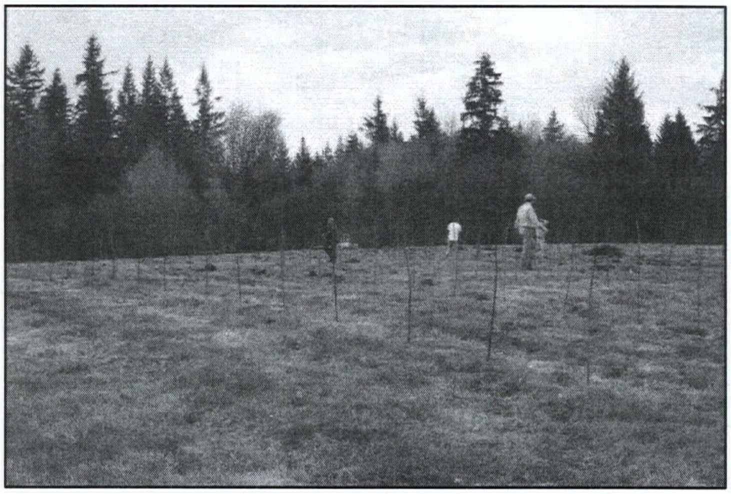
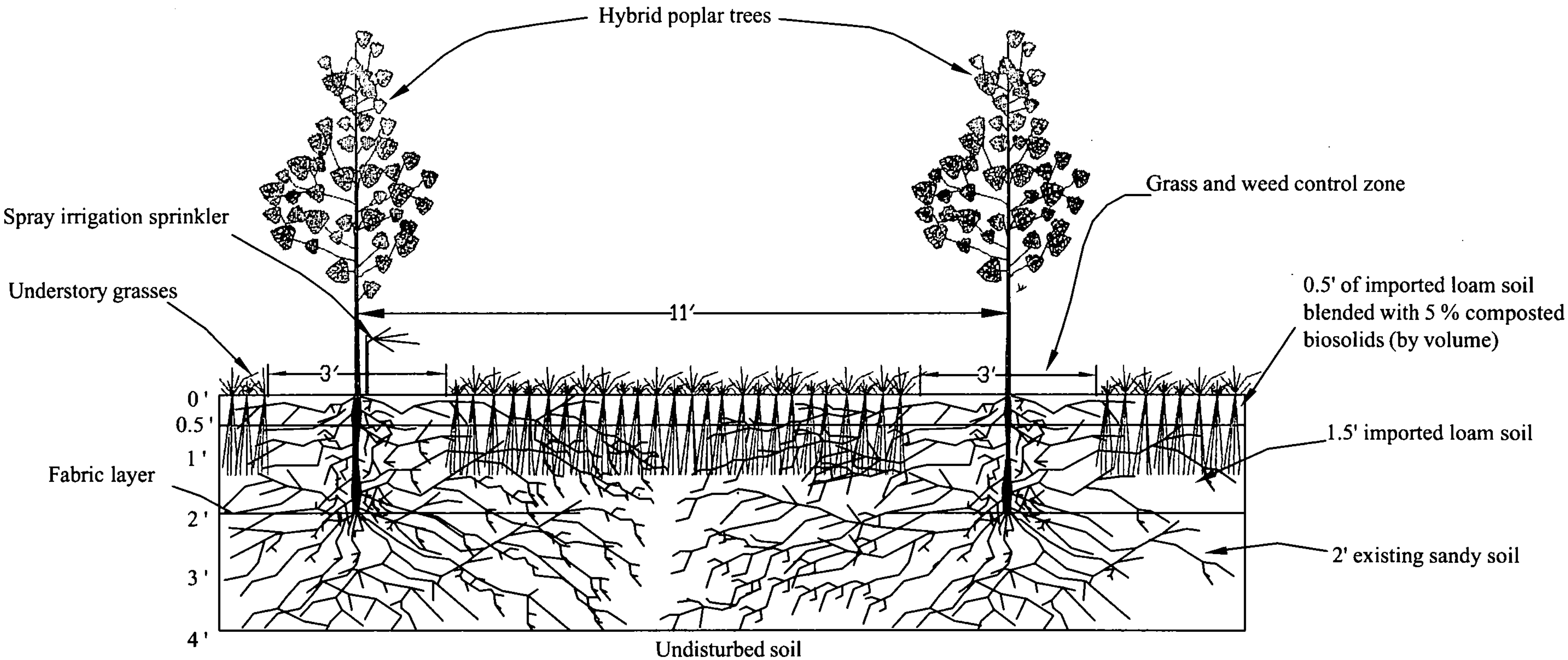


Figure 2. A recently installed 13-acre ECap™ at the Duvall Custodial Landfill, Duvall, Washington (April 2000)

Figure 3. Three years after installing an ECap™ at the Duvall Custodial Landfill

Figure 4. Four years after installing an ECap™ at the Duvall Custodial Landfill. Hydraulic data monitored at this site has been used to estimate the poplar crop coefficient, determine root depth influence on water uptake, and to evaluate the complete water balance.

Figure 5. 25 years after interplanting hybrid poplar and western red cedar at a Washington State University research farm near Puyallup, Washington



Ecolotree, Inc. 3017 Valley View Lane North Liberty, IA 52317	Figure 6. ET cover design option #1 - hybrid poplar trees and understory grasses	SCALE: NOT TO SCALE FILE ID: 2004.13 DRAWN: Aaron Shultz DATE: 5/26/2004 REVISED: 6/15/2004

Figure 6 = ECap cross-section CAD drawing

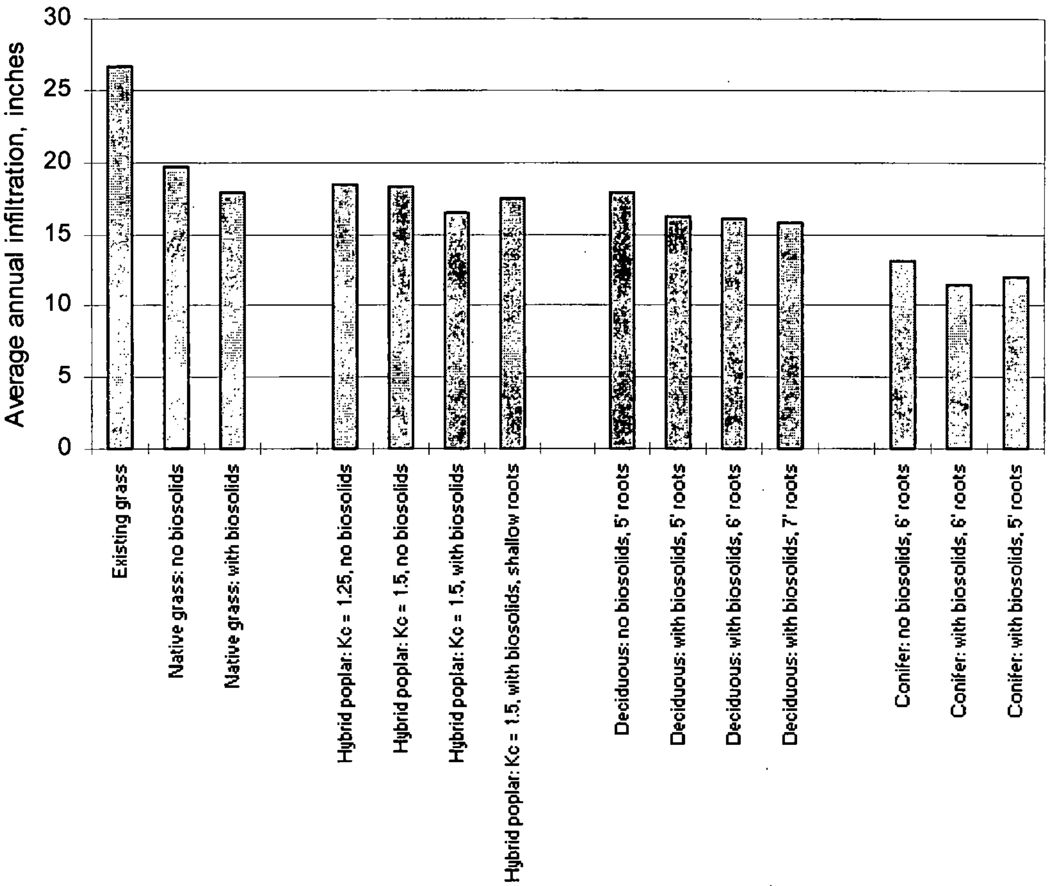


Figure 7. Average annual infiltration results between 1992-2003 for the modeled cover design options

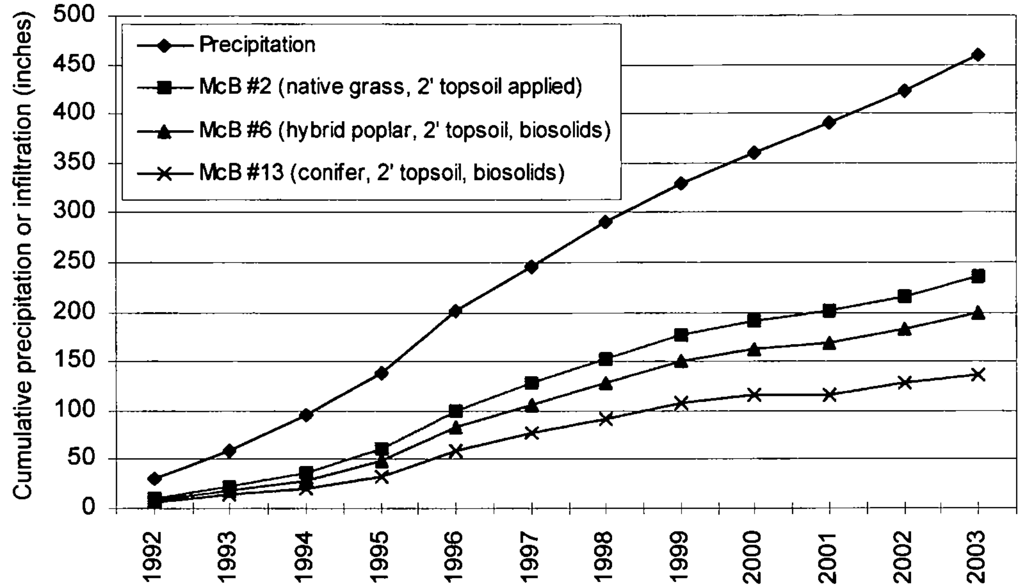
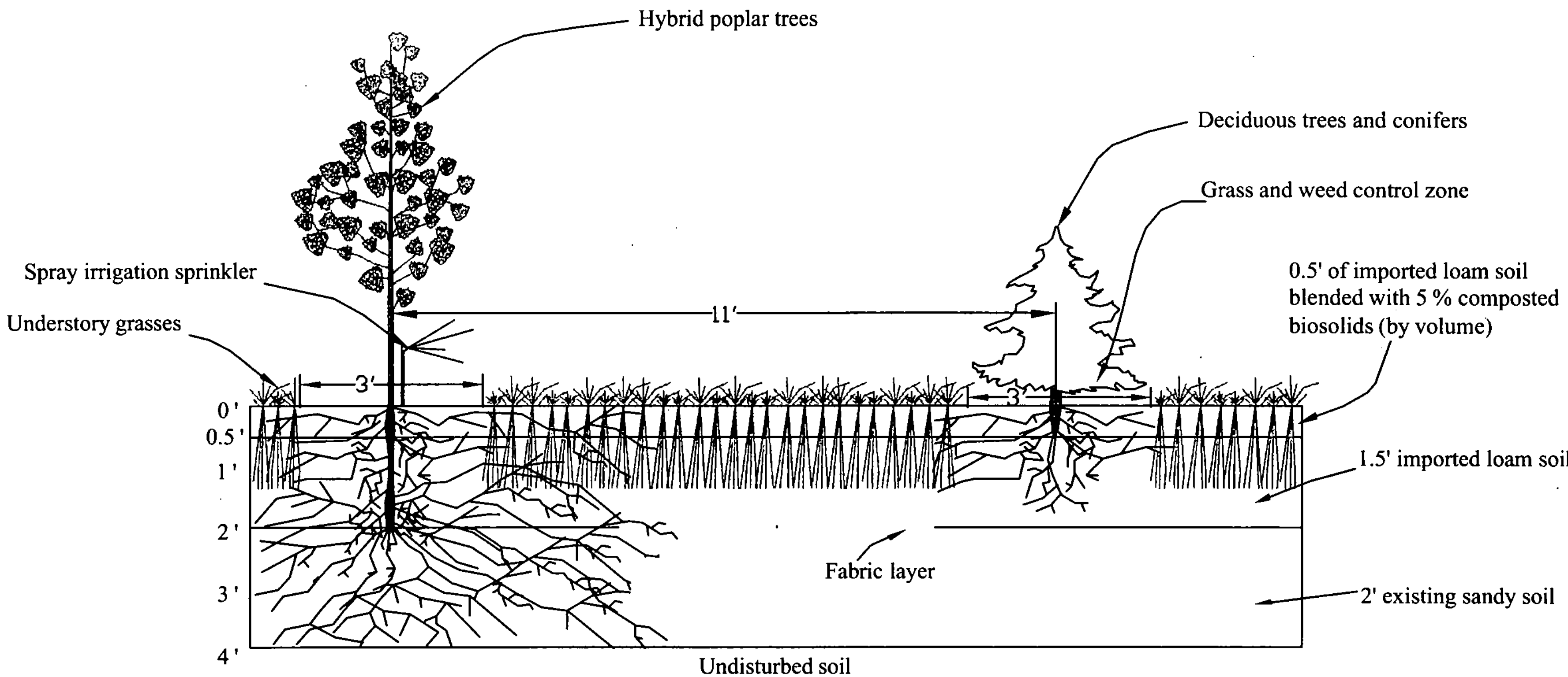
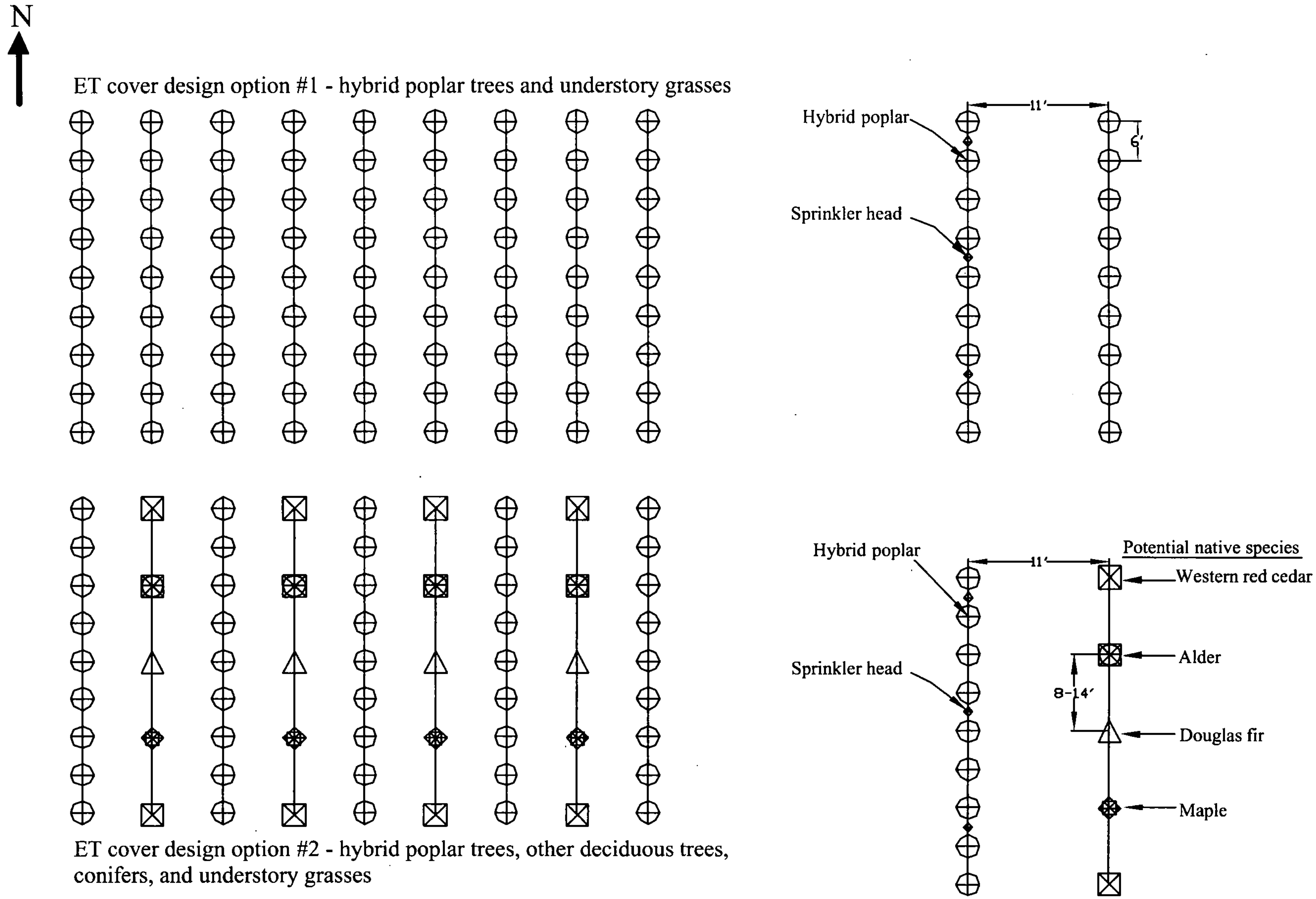


Figure 8. Cumulative precipitation and infiltration values for select cover types, as utilized in or determined by HYDRUS modeling

Figure 9. Cross section CAD drawing showing mixed species layout.



Ecolotree, Inc. 3017 Valley View Lane North Liberty, IA 52317	Figure 9. ET cover design option #2 - hybrid poplar trees, other desciduous trees, conifers, and understory grasses	SCALE: FILE ID: DRAWN: DATE: REVISED:	NOT TO SCALE 2004.13 Aaron Shultz 5/26/2004 6/14/2004



Ecolotree, Inc. 3017 Valley View Lane North Liberty, IA 52317	Figure 10. Plan view layout of ET cover design options	SCALE: NOT TO SCALE FILE ID: 2004.12 DRAWN: A. Shultz DATE: 5/27/2004 REVISED: 6/15/2004

Figure 10. Plan view CAD drawing of two ET cover options

Appendix A:

Biosolids as An Amendment at McCormick and Baxter

Abstract

The City of Portland Bureau of Environmental Services produces biosolids – the solid residue produced by microbial digestion of soluble substances in wastewater – at the Columbia Boulevard wastewater treatment plant. Currently, they apply these biosolids in eastern Oregon on the Madison Ranch land. These biosolids are applied at agronomic rates to grow cattle feed, control erosion, and improve the soil structure and tilth.

Madison Ranches converts biosolids into an asset. Details of this program are found in the "City of Portland Bureau of Environmental Services Biosolids Management Plan," with a summary at the end of this appendix.

Biosolids have been successfully used at an ECap™ landfill cover site located in King County, Washington. Biosolids application had the single greatest impact on growth. In the first two years following application of BioGro (composted Class 1 biosolids) from the City of Seattle, the growth rate was 400% greater. This improved growth was attributed to macronutrients and micronutrients in the biosolids.

To reduce water infiltration into subsoil, plant evapotranspiration can be improved with a deep-rooted plant system and a large annual yield of biomass. With time, the winter evaporation from plant surfaces can be increased by a transition to conifers from hardwoods. In all cases, poor soil structure and nutrition will slow plant development.

The McCormick and Baxter site soils are poor sediment sand in need of improved soil structure, nutrients, and tilth. The biosolids could be applied in mass to the existing sediment soil surface, incorporated to a 2-3 foot depth below ground surface, and provide long-term benefits to the growth rate and health of plants. This biosolid-rich soil would be covered with a separate two foot layer of loam soil imported to the site via barge.

Questions

1. *Can the City of Portland make biosolids available for the McCormick and Baxter construction schedule?* Yes. However, to be part of the final closure plan decisions need to be made quickly regarding bids for dredging, dewatering, and hauling. Mark Ronayne, the City of Portland Biosolids/Reuse Program Manager, is a valuable contact in all aspects of procedures, options, permits, and contractors.

2. *How can all permits with EPA, ODEQ, and City of Portland be achieved?* All proposals detailing biosolid mass, delivery schedule, and special requirements as dictated by the

Record of Decision would be submitted to the wastewater treatment plant superintendent (Dan Clark). Options exist for who enters into contract.

3. *Are the biosolids safe?* The Columbia Boulevard water treatment plant has old, lagooned solids from treated domestic sewage sludge that has zones with lead that exceeds land application limits. Biosolids may technically exceed land application standards for agricultural crops, but would be available for a one-time, buried construction event on the existing site soils before placement of the final 2 foot soil cover layer.

4. *Can biosolids delivery be accomplished within expectations of neighborhood owners?* The McCormick and Baxter site is located within six miles of the Columbia Boulevard plant. Most of the roadway to the site is via industrial truck corridors.

5. *What are the costs and who pays?* The cost table is attached for the current system. One ton of applied and monitored biosolids costs approximately $240 for the City of Portland. The city benefits by removing these older biosolids from their inventory. The whole system benefits, because there will be less diesel, road risk, and truck wear if these biosolids could be applied at the McCormick and Baxter site from the Columbia Boulevard plant.

Cost Estimate for Current City of Portland Biosolids Cake Dry Matter Content	**22%**	
	$/wet tone	**$/dry ton**
Dredge Old Lagoon	$ 8.91	$ 40.50
Dewater to 22% - 24% Dry Matter	$ 12.54	$ 57.00
Current Cost Estimate for Biosolids FOB City of Portland	**$ 21.45**	**$ 97.50**
Hauling to eastern Oregon in 35 ton trucks	$ 20.00	$ 90.90
Land application by K & S Madison	$ 11.35	$ 51.61
Current Cost Estimate for Biosolids Haul and Application	**$ 31.35**	**$ 142.51**
Current cost for Portland Biosolids land application	**$ 52.80**	**$ 240.01**

6. *Who pays for what and why?* This needs to be negotiated, beginning with a proposal to Superintendent Clark.

7. *Who could be a specific technical support for this task?* Mark Ronayne, Biosolids Program Director, suggested Dr. Sally Brown, University of Washington. She has studied brownfield reclamation using biosolids in soils remediation.

These questions and responses are based on phone and email conversations dated 4/2/04, 4/6/04, 4/28/04, 5/24/04, 6/10/04.

Recommended Approach

When site construction begins to finish the surface, biosolids would need to be hauled to the site. If it were possible to incorporate 100 dry tons of biosolids per acre mixed well into two feet of the existing sediment soils, the final soil would contain 5 - 6% biosolids. This assumes a density of about 1.6 million pounds per acre-foot of soil. This organic matter content could provide the sandy soils with more loam-like properties and greater exchangeable water holding capacities.

If this approach occurred on 10 acres, the site would require 1,000 tons of biosolids dry matter during the 2004 construction season. This is actually 4,550 wet tons of biosolids at 22% dry matter.

If the biosolids are produced and delivered over a 100 day period, the daily throughput through the dredge and dewatering system would need to be 10 dry tons per day, or approximately 45 wet biosolids cake at 22% dry matter. The City of Portland has stated that biosolid production and availability could be sped up if required by site construction.

The land application and incorporation into existing sandy soils must occur before the placement of the top two foot surface soil layer. Therefore, the biosolids could be delivered, dumped, and immediately incorporated using ripping, trenching, rototilling, and plowing techniques. Agricultural-type equipment could be used for incorporation. Fortunately, the site is sandy and expected to drain well during the wet spring period. Fall 2004 would work best if possible because the soil will be driest and work up well.

If the site managers and regulators are comfortable with the concept of a biosolid amendment in the top two foot soil layer, another 300-500 tons of biosolids can be incorporated around the site to improve plant survival and growth.

Excerpt from the "City of Portland Bureau of Environmental Services Biosolids Management Plan" Report

Sufficient area has been authorized at Madison Farms to assimilate 17,609 dry tons of Portland biosolids in 2004, 28 percent more solids (16,353 dry tons) than were applied in 2003 (12,736.5 dry tons).

Biosolids improved soils by providing organic matter and nutrients. Their application has also significantly benefited upland soils at Madison Farms by mitigating problems of soil erosion and low soil productivity. Organic matter provides a food source for soil microbes; increases the soil's ability to conserve water, making more water available for plant uptake; ties up trace organic compounds such as pesticides, lessening their tendency to leach and continue to exert undesirable toxic effects; stabilizes soil by binding soil particles together, stemming wind and water erosion; and it adds to soil tilth.

Although not considered a high-grade fertilizer, biosolids contain plant nutrients including nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, manganese, iron, copper, zinc and molybdenum. Nitrogen, phosphorus, potassium and other plant-essential nutrients supplied by

Portland biosolids contribute to long-term improvements in soil fertility. Biosolids application rates are designed to meet the nitrogen requirements of the crop. On some soils, such as occur at Madison Farms, micronutrients supplied by biosolids may improve crop yields. However, many of the trace and micronutrients available in biosolids are not economically feasible to land apply commercially, particularly to dry land forage operations.

In May 1997, Portland biosolids amended and adjacent non-amended areas were examined to determine if solids land application had affected physical properties in the top six inches of the soil profile. The addition of biosolids decreased soil bulk density and increased total soil porosity, organic matter and available water holding capacity.

Table 13-6. An Estimate of Organic Matter and Nutrients in Biosolids Applied to Madison Farms-2003

Constituent	Percent dry weight	Lb/dry ton	Lb/ac/yr[3]	Tons/year
Organic matter	57.1	1,142	4,796	7,273
Total N	4.9	97.93	411.3	633.5
NH_4-N[4]	0.66	13.16	55.3	84
P_2O_5[5]	5.78 (2.53)	115.64 (50.5)	485.7 (212)	736 (321.6)
K_20[6]	0.35 (0.29)	7.08 (5.81)	29.8 (24)	45.8 (37)
Calcium	2.15	43	181	274
Magnesium	0.63	12.6	53	80
Sulfur	1.03	20.6	87	131
Iron	1.59	31.8	134	203
Copper	0.05	1	4	6
Zinc	0.11	2.2	9	14
Manganese	0.04	0.8	3	5
Boron	0.0042	0.084	0.35	0.5

[1]Mean of three samples collected by Portland Biosolids Management Program staff on August 19, 20, and 21, 2002.
[2]Samples tested by Agri-Check, Inc., in August 26, 2002. Biosolids were acid digested pursuant to Soil Science Society of nerica Book Series 3; Soil Testing and Plant Analysis; 1990; p. 406. Samples were then analyzed on a Perkin Elmer ICP, ries 3000DV unit.
[3]Based on an average application rate of 4.2 dry tons biosolids per acre during 2003.
[4]The NH_4-N analysis was done after biosolids were dried. Thus, results are lower than typically found when biosolids are ocessed by Portland's WPCL pursuant to EPA Method 350.1.
[5]Upper value denotes P_2O_5 and lower value indicates total P.
[6]Upper value denotes K_2O and lower value indicates total K.

Table 13-7. Soil Quality (0-3") in Biosolids and Non-Biosolids Amended Areas of Madison Farms-2003 [1&2]			
Parameter [3&4]	Unamended Area[5]	Amended Area	Change (%)
OM (%)	1.3	3.2	+146
Phosphorus (mg/kg)	18	122	+578
Potassium (mg/kg)	313	418	+34
NO_3-N (mg/kg)	4	9	+125
NH_4-N (mg/kg)	1	13	+1,200
Mineralizable N (mg/kg)	37.2	60.2	+62%
Calcium (meq/100g)	6.9	6.1	-12
Magnesium (meq/100g)	1.5	1.9	+27
Boron (mg/kg)	0.3	0.3	No change
Zinc (mg/kg)	0.3	12.5	+4,067
Copper (mg/kg)	0.5	8.5	+1,600
Iron (mg/kg)	9	42	+367
Manganese (mg/kg)	3	32	+967
Total Bases (meq/100g)	9.2	9.1	-1
pH	7.2	6	-17
Elec. Conductivity	0.08	0.18	+125

[1]Based on the content of the constituent detected in the upper topsoil (0 to 3") of biosolids and non-biosolids amended areas of Madison Farms. Soil samples were collected from a control area and nearby biosolids amended area of Madison Farms in Section 11, Township 3 North, Range 27 East, Willamette Meridian, by Dr. Don Horneck, Oregon State University Inc., on April 25, 2003, soils were analyzed by Agri-Check, Inc.

[2]Biosolids amended sites had received up to 62 to 66 dry tons of biosolids at rates ranging from 3.57 to 5.0 dry tons per acre per year commencing in early April 1990. Biosolids were applied in liquid form between April 8, 1990 and July 8, 1991 (the first 5.0 dry ton installment) and in dewatered form (3.57 to 5.0 dry ton installments) since that time, commencing July 20, 1992.

[3] Measurement unit is listed beside the parameter (indicated in parenthesis).

[4]Values represent bicarbonate extractable phosphorus, exchangeable potassium, exchangeable calcium, exchangeable magnesium, extractable sulfate-S, hot water extractable boron, DTPA extractable zinc, DTPA extractable manganese, DTPA extractable iron, and DTPA extractable copper concentrations in biosolids and non-biosolids amended soils.

[5]Data based on soil testing of samples collected by Dr. Don Horneck from non-biosolids amended BLM land in Section 2 near amended sites in Section 11 in April 25, 2003.

To help characterize the influence that biosolids have had on forage quality, comparisons of biomass and forage fertility levels were made from amended and non-amended sites in the same immediate vicinity of Section 11 (Table 13-10). Biomass on the amended area was over six times greater than biomass on the non-amended control (2,208 lb./ac on the amended site versus 353 pounds per acre on the non-amended site). Biomass production on biosolids amended lands is largely dependent on weather conditions (e.g., precipitation and ambient temperature). Biomass in 2003 was somewhat lower than it was in 2000, 2001 and 2002 (2,208 lb./ac-2003 versus 5,968 lb./ac-2000, 5,211 lb./ac-2001 and 3,943 lb.ac-2002); possibly due to a dry fall in 2002 followed by cool, moist, spring weather in 2003. Although important, weather conditions seem to play a lesser role in affecting biomass production on non-biosolids amended soils. Biomass levels, because of other limitations, varied less widely at the same non-amended control sites during 1998, 1999, 2000, 2001, 2002 and 2003 (i.e., 353 lb./ac-2003 versus 668 lb./ac-2002, 1,145 lb./ac-2001, 889 lb./ac-2000, 855 lb./ac-1999 and 841 lb./ac-1998). Biomass on non-amended sites appears to be more influenced by soil fertility levels than seasonal weather conditions.

Biosolids land application has significantly improved forage value. The per acre biomass protein content in amended forage areas was approximately 15 times higher than it was in non-biosolids amended forage (68.8 lb./ac versus 4.5 lb./ac) (Table 13-11). In addition, the acid detergent and neutral detergent fiber content in biosolids amended forage was lower than in non-amended forage, verifying that biosolids amended grasses were more readily digestible. The early spring grass protein content (e.g., April 1998 and 1999) in biosolids amended areas was historically in the range of high quality alfalfa (> 18%) (1999 Biosolids Management Plan; Section 13). On a per acre yield basis, the mass of total nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, boron, zinc, manganese, copper, iron and sodium present in above-ground forage biomass increased four to thirty-two times on biosolids amended land (Table 13-11).

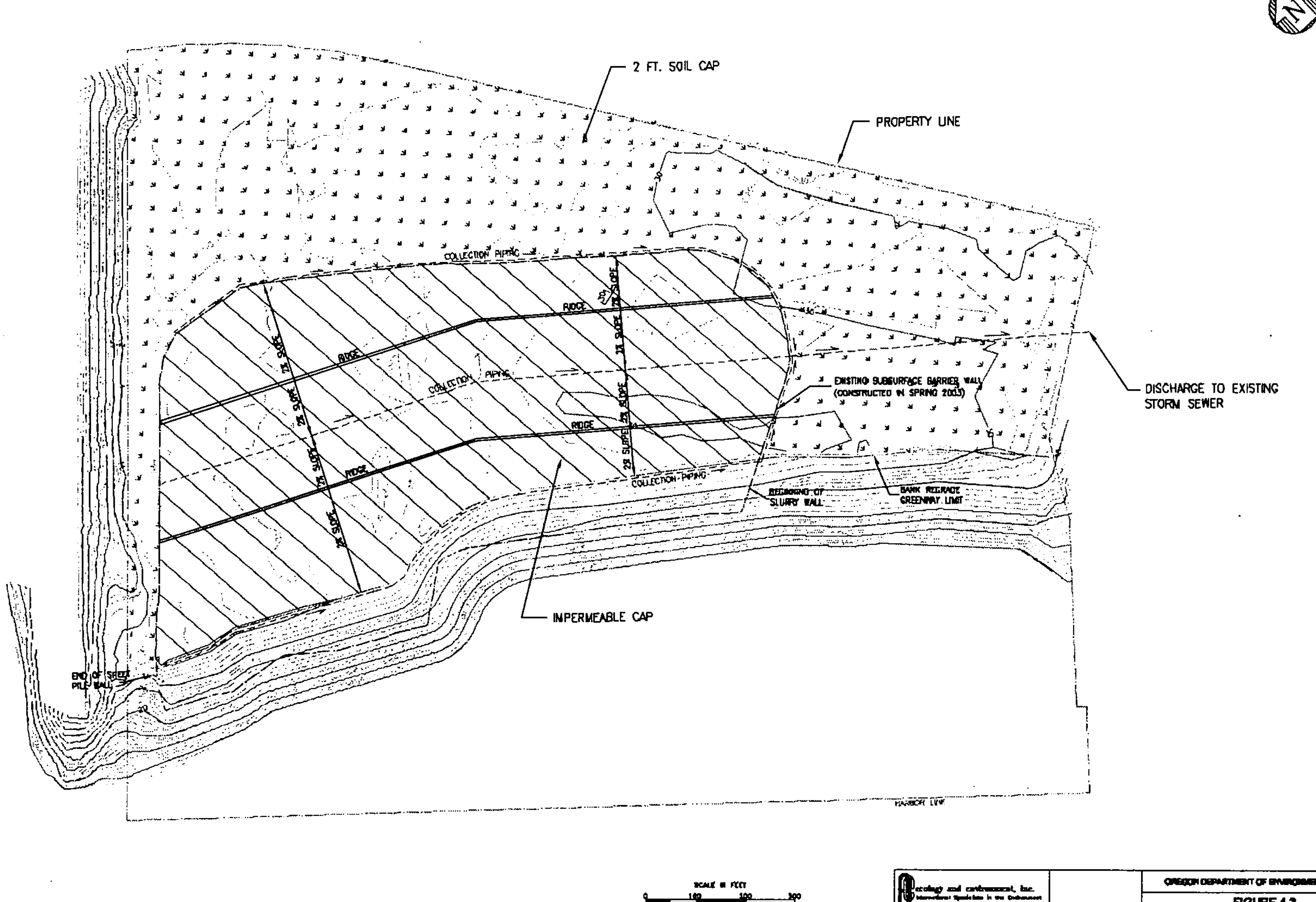
Table 13-11. A Comparison of Nutrient Levels in Biosolids and Non-Biosolids Amended Forage at Madison Farms - 2003[1,2&3]

Nutrient	Concentration		lb./ac	
	Amended	Non-Amended	Amended	Non-Amended
Total N (%)	2.45	1.27	54.1	4.48
Nitrate-N (mg/kg)	406	79	0.897	0.028
Sulfur (%)	0.2	0.12	4.42	0.42
Phosphorus (%)	0.25	0.21	5.52	0.74
Potassium (%)	1.97	1.28	43.5	4.52
Calcium (%)	0.58	0.56	12.81	1.98
Magnesium (%)	0.15	0.17	3.31	0.6
Boron (mg/kg)	7	10	0.015	0.004
Zinc (mg/kg)	21	13	0.046	0.005
Manganese (mg/kg)	101	56	0.223	0.02
Copper (mg/kg)	8	5	0.018	0.002
Iron (mg/kg)	585	348	1.292	0.123
Molybdenum (mg/kg)	0.49	0.56	0.001808	0.000198
Sodium (mg/kg)	56	47	0.124	0.017

[1]Sampled by Dr. Don Horneck, OSU, on April 25, 2003.

[2]Subsamples were composited into a single sample, each, from amended and non-amended areas of Sections 11 and 2, respectively, in Township 3 North, Range 27, East, Willamette Meridian, Umatilla County, Oregon. Amended and control areas were similar soils on the same landform. Amended and control sites were approximately 50 feet apart.

[3]Analyzed by Agri-Check, Inc.



ecology and environment, inc.

Portland, Oregon

CHECKED BY

A. WHITMAN

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

FIGURE 4-3
CONCEPTUAL PLAN:
IMPERMEABLE CAP

APPENDIX B

Cost Estimates

APPENDIX C

Schedules

CONSTRUCTION COST SUMMARY
EVAPOTRANSPIRATION COVER - PREFINAL DESIGN

McCormick & Baxter Creosoting Company Site
Portland, Oregon

Item #	Description	Cost
1a	Mobilization/Demobilization	$274,800
1b	Plans and Submittals	$50,000
1c	Pre-Construction Surveying	$9,200
1d	Surveying during Construction	$85,400
1e	Post-Construction Surveying	$9,200
1f	Quality Control During Construction	$40,000
2a	Clearing	$3,100
2b	Relocating Large Woody Debris	$5,950
2c	Utility Abandonment	$12,900
2d	Structure Demolition	$37,800
2e	Monitoring Well Abandonment	$33,800
2f	RCRA Haz Waste Management	$150,000
2g	Non-Haz Waste Management	$32,000
2h	Erosion and Sedimentation Control	$5,800
3a	Site Smoothing	$62,400
3b	Demarcation Fabric Installation	$102,100
3c	Base Fill for Contour Development	$328,300
3d	Perimeter Trench Excavation	$8,000
3e	2' Soil Cap Fill	$1,742,500
3f	Vegetation	$248,400
3g	Asphalt Paving	$103,400
Subtotal Construction Costs:		**$3,345,100**
	Construction Contingencies (+15%)	$501,765
	Admin & Construction Oversight (+15%)	$501,765
Total Construction Costs:		**$4,349,000**

Cost Worksheet

Prefinal Design (90%)

Pay Item Number: 1
Description: General

Project: McCormick & Baxter - Evapotranspiration Cover
Location: Portland, Oregon
Base Year: 2004

Work Statement and Assumptions:

Work Statement: This element includes Mobilization/Demobilization (Item 1a); Submittal Preparation (Item 1b); Pre-Construction Surveying (Item 1c); Survyeing during Construction (Item 1d); Post-Construction Surveying (Item 1e); and Quality Control During Construction (Item 1f).

Assumptions:
1. Assume time of field work Nov. 30, 2004 to July 6, 2005 (8 months).
2. Assume 2 job trailers are used.
3. Surveying:
   *Preconstruction Survey: assume 3 man crew for 3 days field plus 2 man office for 5 days
   *Surveying during Construction: assume 2 man crew for 4 months.
   *Postconstruction Surveying: assume 3 man crew for 3 days plus 2 man office for 5 days

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
1a - Mobilization/Demobilization									
Trailers-2	16	MO		$185		$185	$2,965	HCCD 01520-500-0350	
Site Superintendent	8	MO	$10,933			$10,933	$87,464	HCCD 01300-700-0260	
Clerk	8	MO	$2,337			$2,337	$18,699	HCCD 01300-700-0010	
Project Manager	8	MO	$11,876			$11,876	$95,004	HCCD 01300-700-0200	
Field Engineer	8	MO	$7,238			$7,238	$57,907	HCCD 01310-700-0120	
Electric	8	MO		$226		$226	$1,808	Engineering Estimate	
Electric Install	1	EA	$548	$1,526	$153	$2,227	$2,227	HCCD 01510-050-0130	
Telephone - 2 lines	16	MO		$113		$113	$1,808	Engineering Estimate	
Portable Toilet - 4	32	MO		$176.28		$176	$5,641	HCCD 01590-400-6410	
Field Office Expenses	8	MO		$157.07		$157	$1,257	HCCD 01520-550-0100	
Water							By ODEQ		
1a Subtotal							*$274,800*		

1b - Construction Operations Plan, Quality Control Plan, Site Safety Plan, and Other Submittals									
Plans		LS					$50,000	Engineering Estimate	
1b Subtotal							*$50,000*		
1c - Pre-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1c Subtotal							*$9,200*		
1d - Surveying During Construction									
HCCD Crew A-7, 2-man	87	DAY	$914.54	$67.24	$0.41	$982.19	$85,400	HCCD Crews	
1d Subtotal							*$85,400*		
1e - Post-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1e Subtotal							*$9,200*		
1f - Quality Control During Construction									
Quality Control		LS					$40,000	Engineering Estimate	
1f Subtotal							*$40,000*		
PAY ITEM 1 TOTAL							**$468,600**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).

Cost Worksheet

Prefinal Design (90%)

Pay Item Number: 2
Description: Removal, On-Site Consolidation and Stabilization, and Off-Site Disposal

Project: McCormick & Baxter - Evapotranspiration Cover
Location: Portland, Oregon
Base Year: 2004

Work Statement and Assumptions:

Work Statement: This element includes Clearing (Item 2a); Relocating Large Woody Debris (Item 2b); Utility Abandonment (Item 2c); Structure Demolition (Item 2d); Monitoring Well Abandonment (Item 2e); RCRA Hazardous Waste Handling, Transportation, and Off-Site Disposal (Item 2f); Non-Hazardous Waste Handling, Transportation, and Off-Site Disposal; and Erosion and Sedimentation Control (Item 2h).

Assumptions:
1. Assume 50% of the upland portion of the site will require selective clearing: 17.1 acres
2. Assume 10 tons of large woody debris will require consolidation and removal.
3. Utility abandonment assumptions:
   *Water: 1365 ft. of waterline to be abandoned with grout; 10 hydrants removed
   *Electric: 500 ft. of electric lines removed; 5 utilty poles removed
4. Building demolition assumptions:
   *Shop building: 45 ft. x 60 ft. x 20 ft = 54,000 cf; 2700 sf foundation, 6" thick
   *Assume soil beneath 1/2 of building contaminated to 4' bgs. Resulting soil volume = 200 cy = 240 tons (assuming 1.2 tons/cy)
   *Connex box: 3,200 cf
   *Tank: assume 5,000 gallons
5. Monitoring well abandonment: assume 20 monitoring wells to be abandoned; 40 feet deep each or 800 vertical linear feet (vlf)
6. RCRA haz. waste: assume 240 tons soil (per #4, above) plus 10 tons misc.
7. Non-haz. waste: assume 500 tons
8. Erosion control assumptions:
   *Silt fence around site perimeter: 5,561 linear feet
   *Straw bales: 500 linear feet

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
2a - Clearing									
Selective clearing, with dozer and brush rake, light	17	ACRE	$83	$98		$180	$3,100	HCCD 02230-200-0010	
2a Subtotal							*$3,100*		
2b - Relocating Large Woody Debris									
HCCD Crew B-10U	1	DAY	$649	$762.52		$1,412	$1,412	HCCD Crews	
HCCD Crew B-13C	1	DAY	$2,728	$1,810.26		$4,539	$4,539	HCCD Crews	

2b Subtotal							*$5,950*		
2c - Utility Abandonment									
Abandon water piping	1,365	LF	$2.13	$0.47		$3	$3,556	HCCD-02220-875-2900	
Fire hydrant removal	10	EA	$445	$109.05		$554	$5,545	HCCD 02220-240-0900	
Abandon electric lines	500	LF	$2.18	$0.45		$2.63	$1,314	Engineering Estimate	
Remove utility poles	5	EA				$500	$2,500	Engineering Estimate	
2c Subtotal							*$12,900*		
2d - Structure Demolition									
Steel building demolition, shop	54,000	CF	$0.16	$0.14		$0.29	$15,779	HCCD 02220-110-0500	
Demo 6" conc. slab on grade	2,700	SF	$4.91	$0.49		$5.39	$14,560	HCCD 02220-130-0420	
Excavate contaminated soil	200	CY	$0.98	$1.10		$2.09	$417	HCCD 02315-424-0260	
Steel building demolition, conex box	3,200	CF	$0.16	$0.14		$0.29	$935	HCCD 02220-110-0500	
Remove tank to 5,000 gal	1	EA	$1,039.79	$97.50		$1,137	$1,137	ERCD 16-01-9033	
Misc. item removal		JOB					$5,000	Engineering Estimate	
2d Subtotal							*$37,800*		
2e - Monitoring Well Abandonment									
Well abandonment	800	VLF				$42.22	$33,800	Remtech unit price	
2e Subtotal							*$33,800*		
2f - RCRA Hazardous Waste Handling, Transportation, and Off-Site Disposal									
Contaminated soil beneath shop building	240	TONS				$600	$144,000	Remtech unit price	
Misc. waste	10	TONS				$601	$6,010	Remtech unit price	
2f Subtotal							*$150,000*		
2g - Non-Hazardous Waste Handling, Transportation, and Off-Site Disposal									
Non-haz waste	500	TONS				$64.00	$32,000	Remtech unit price	
2g Subtotal							*$32,000*		
2h - Erosion and Sedimentation Control									
Silt Fence, polypropylene	5,561	LF	$0.45		$0.34	$0.79	$4,401	HCCD 02370-700-1000	
Hay Bales, Staked	500	LF	$0.44	$0.06	$2.35	$2.84	$1,421	HCCD 02370-700-1250	
2h Subtotal							*$5,800*		
PAY ITEM 2 TOTAL							**$281,400**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).
R.S. Means, 2004, Environmental Remediation Cost Data 10th Annual Edition (ERCD).

Cost Worksheet

Prefinal Design (90%)

Pay Item Number:	3
Description:	Earthwork, Geosynthetics, and Paving
Project:	McCormick & Baxter - Evapotranspiration Cover
Location:	Portland, Oregon
Base Year:	2004

Work Statement and Assumptions:

Work Statement: This element includes the following work items: Site Smoothing (Item 3a); Demarcation Fabric Installation (Item 3b); Base Fill for Contour Development (Item 3c); 2' Soil Cap Fill (Item 3d); Vegetation (Item 3e); and Asphalt Paving (Item 3f).

Assumptions:
1. Assume site smoothing/grading over entire site: 34.01 acres = 164,600 sy.
2. Assume demarcation fabric installed over entire site: 34.01 acres = 164,600 sy.
3. Contour Development: Assume a 0.5% grade within barrier wall for positive drainage. Barrier wall area (upland from greenway) = 14.94 acres = 72,300 sy. To achieve 0.5% grade within this area, assume a 1,250 feet long ridge along the approx. centerline of the barrier wall area running NW to SE, with 0..5% slopes towards the bluff and the river. Assuming an average slope length of 250 feet (i.e., the distance from the ridge to the barrier wall & greenway limit), the calculated ridge height along the centerline is 1.25 feet. The resulting required volume of additional fill = 1/2 (length x width x heighth) = 1/2 (1250 feet x 500 feet x 1.25 feet) = 390,625 cubic feet = 14,470 cubic yards = 15,900 tons (assuming 1.1 tons/cubic yard). Assume St. Helens topsoil material will be used to for this contour development.
4. Assume average haul distance from stockpile to barrier wall area for contour development = 1/4 mile roundtrip.
5. Assume a 2' deep perimeter trench will be excavated at the site permiter along the BNRR, UPRR, and Triangle Park property lines. Resulting trench length = 4680 ft. Assuming 3:1 slope to trench bottom. Resulting excavation volume = 1040 cy. Assume material is spread within site (prior to demarcation layer placement).
6. Assume 2 feet soil cap fill depth over entire site, less asphalt entrance area (0.97 acres). Soil cap area = 34.1 acres - 0.97 acres = 33.13 acres = 160,350 sy. Cap volume = 106,900 cy = 117,600 tons (assuming 1.1 tons/cy).
7. Assume soil cap will be vegetated with native upper riparian vegetation (seeding and plantings), per City of Portland.
8. Assume site entrance asphalt area will be capped and repaved. Total paved area = 1.08 acres = 47,050 sf = 5,230 sy. [Note, a portion of the paved area (0.11 acres) is outside of the property boundary. Assume this area will also be repaved]. The following layers will be placed to achieve a 2' thick cap over this area: 1" asphalt top course over 3" asphalt binder course over 6" crushed rock over 14" select granular fill.

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
3a - Site Smoothing									
Grade subgrade	164,600	SY	$0.24	$0.14		$0.38	$62,400	HCCD 02310-100-0200	
3a Subtotal							*$62,400*		

3b - Demarcation Fabric Installation									
Install HDPE Fabric	164,600	SY				$0.62	$102,100	Remtech Unit Price	
3b Subtotal							*$102,100*		
3c - Base Fill for Contour Development									
Soil fill material (St. Helen's topsoil), stockpiled on-site	15,900	TONS				$10.00	$159,000	Remtech Unit Price	
Load soil from stockpile onto dumptruck; front end loader, 5 cy bucket	14,470	CY	$0.24	$0.29		$0.54	$7,776	HCCD 02315-210-7080	
Haul soil, 12 cy dump truck, 1/4 mile round trip	14,470	CY	$1.27	$1.88		$3.15	$45,523	HCCD 02315-490-0310	
Spread dumped material; by dozer, no compaction	14,470	CY	$0.64	$0.97		$1.62	$23,378	HCCD 02315-520-0020	
Rough grading, 14G, 1 pass	72,300	SY	$0.59	$0.69		$1.28	$92,600	ERCD 17-03-0103	
3c Subtotal							*$328,300*		
3d - Perimeter Trench Excavation									
Trench Excavating, 1ft. to 4ft. deep; hydraulic backhoe	1,040	CY	$3.31	$1.92		$5.23	$5,400	HCCD 02315-610-0062	
Spread fill with loader, 300' haul	1,041	CY	$1.08	$1.44		$2.51	$2,600	HCCD 02315-520-0170	
3d Subtotal							*$8,000*		
3e - 2' Soil Cap Fill									
Soil fill material (St. Helen's topsoil), stockpiled on-site	117,600	TONS				$10.00	$1,176,000	Remtech Unit Price	
Load soil from stockpile onto dumptruck; front end loader, 5 cy bucket	106,900	CY	$0.24	$0.29		$0.54	$57,448	HCCD 02315-210-7080	
Haul soil, 12 cy dump truck, 1/4 mile round trip	106,900	CY	$1.27	$1.88		$3.15	$336,307	HCCD 02315-490-0310	
Spread dumped material; by dozer, no compaction	106,900	CY	$0.64	$0.97		$1.62	$172,708	HCCD 02315-520-0020	
3e Subtotal							*$1,742,500*		
3f - Vegetation									

Seeding	33.13	ACRE	$84.66		$1,627.81	$1,712.47	$56,734	City of Portland	
Plantings	33.13	ACRE				$5,284.60	$175,079	City of Portland	1
Fertilizer	33.13	ACRE				$500.00	$16,565	Ecolotree	
3f Subtotal							*$248,400*		

3g - Asphalt Paving									
Select granular fill placed with front end loader (14" deep)	2,034	CY	$0.38	$0.19	$8.48	$9.05	$18,406	HCCD 02315-210-5070	
Crushed 1-1/2" stone base, compacted to 6" deep	5,230	SY	$0.63	$0.58	$6.72	$7.93	$41,454	HCCD 02740-200-0302	
Asphalt concrete pavement, lots; 3" thick binder course, 1" thick topping	47,050	SF	$0.16	$0.12	$0.64	$0.93	$43,521	HCCD 02740-315-0500	
3g Subtotal							*$103,400*		
PAY ITEM 3 TOTAL							**$2,587,100**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).
R.S. Means, 2004, Environmental Remediation Cost Data 10th Annual Edition (ERCD).

Notes:

1. Unit price includes mulch and mulch application.

CONSTRUCTION COST SUMMARY
IMPERMEABLE COVER - CONCEPTUAL DESIGN

McCormick & Baxter Creosoting Company Site
Portland, Oregon

Item #	Description	Cost
1a	Mobilization/Demobilization	$377,000
1b	Plans and Submittals	$50,000
1c	Pre-Construction Surveying	$9,200
1d	Surveying during Construction	$128,000
1e	Post-Construction Surveying	$9,200
1f	Quality Control During Construction	$40,000
2a	Clearing	$3,100
2b	Relocating Large Woody Debris	$5,950
2c	Utility Abandonment	$12,900
2d	Structure Demolition	$37,800
2e	Monitoring Well Abandonment	$33,800
2f	RCRA Haz Waste Management	$150,000
2g	Non-Haz Waste Management	$32,000
2h	Erosion and Sedimentation Control	$5,800
3a	Site Smoothing	$62,400
3b	Contour Development (w/in barrier wall)	$564,200
3c	Geosynthetic Clay Liner	$432,900
3d	Flexible Membrane Liner	$1,357,400
3e	Geonet Composite	$372,800
3f	6" Sand Drainage Layer	$201,700
3g	6" Biotic Layer	$201,700
3h	Geotextile Filter	$115,400
3i	12" Topsoil (within barrier wall)	$392,700
3j	Demarcation Layer (outside barrier wall)	$51,700
3k	2' Soil Cap (outside barrier wall)	$905,600
3l	Perimeter Trench Excavation	$8,000
3m	Stormwater Collection & Conveyance	$70,100
3n	Vegetation	$73,300
3o	Asphalt Paving	$103,400
Subtotal Construction Costs:		**$5,808,100**
	Construction Contingencies (+15%)	$871,215
	Admin & Construction Oversight (+15%)	$871,215
Total Construction Costs:		**$7,551,000**

Cost Worksheet

Conceptual Design (50%)

Pay Item Number: 1
Description: General

Project: McCormick & Baxter - Impermeable Cover
Location: Portland, Oregon
Base Year: 2004

Work Statement and Assumptions:

Work Statement: This element includes Mobilization/Demobilization (Item 1a); Submittal Preparation (Item 1b); Pre-Construction Surveying (Item 1c); Survyeing during Construction (Item 1d); Post-Construction Surveying (Item 1e); and Quality Control During Construction (Item 1f).

Assumptions:
1. Assume time of field work Nov.39 2004 to Nov. 24, 2005 (approx. 12 months), less one month (June) of no activity, per Schedule. Total = 11 months.
2. Assume 2 job trailers are used.
3. Surveying:
   *Preconstruction Survey: assume 3 man crew for 3 days field plus 2 man office for 5 days
   *Surveying during Construction: assume 2 man crew for 6 months.
   *Postconstruction Surveying: assume 3 man crew for 3 days plus 2 man office for 5 days

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
1a - Mobilization/Demobilization									
Trailers-2	22	MO		$185		$185	$4,077	HCCD 01520-500-0350	
Site Superintendent	11	MO	$10,933			$10,933	$120,263	HCCD 01300-700-0260	
Clerk	11	MO	$2,337			$2,337	$25,711	HCCD 01300-700-0010	
Project Manager	11	MO	$11,876			$11,876	$130,631	HCCD 01300-700-0200	
Field Engineer	11	MO	$7,238			$7,238	$79,622	HCCD 01310-700-0120	
Electric	11	MO		$226		$226	$2,486	Engineering Estimate	
Electric Install	1	EA	$548	$1,526	$153	$2,227	$2,227	HCCD 01510-050-0130	
Telephone - 2 lines	22	MO		$113		$113	$2,486	Engineering Estimate	
Portable Toilet - 4	44	MO		$176.28		$176	$7,756	HCCD 01590-400-6410	
Field Office Expenses	11	MO		$157.07		$157	$1,728	HCCD 01520-550-0100	
Water							By ODEQ		
1a Subtotal							*$377,000*		

1b - Construction Operations Plan, Quality Control Plan, Site Safety Plan, and Other Submittals									
Plans		LS					$50,000	Engineering Estimate	
1b Subtotal							*$50,000*		
1c - Pre-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1c Subtotal							*$9,200*		
1d - Surveying During Construction									
HCCD Crew A-7, 2-man	130	DAY	$914.54	$67.24	$0.41	$982.19	$128,000	HCCD Crews	
1d Subtotal							*$128,000*		
1e - Post-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1e Subtotal							*$9,200*		
1f - Quality Control During Construction									
Quality Control		LS					$40,000	Engineering Estimate	
1f Subtotal							*$40,000*		
PAY ITEM 1 TOTAL							**$613,400**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).

Cost Worksheet

Conceptual Design (50%)

Pay Item Number: 1
Description: General

Project: McCormick & Baxter - Impermeable Cover
Location: Portland, Oregon
Base Year: 2004

Work Statement and Assumptions:

Work Statement: This element includes Mobilization/Demobilization (Item 1a); Submittal Preparation (Item 1b); Pre-Construction Surveying (Item 1c); Survyeing during Construction (Item 1d); Post-Construction Surveying (Item 1e); and Quality Control During Construction (Item 1f).

Assumptions:

1. Assume time of field work Nov.39 2004 to Nov. 24, 2005 (approx. 12 months), less one month (June) of no activity, per Schedule. Total = 11 months.
2. Assume 2 job trailers are used.
3. Surveying:
   *Preconstruction Survey: assume 3 man crew for 3 days field plus 2 man office for 5 days
   *Surveying during Construction: assume 2 man crew for 6 months.
   *Postconstruction Surveying: assume 3 man crew for 3 days plus 2 man office for 5 days

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
1a - Mobilization/Demobilization									
Trailers-2	22	MO		$185		$185	$4,077	HCCD 01520-500-0350	
Site Superintendent	11	MO	$10,933			$10,933	$120,263	HCCD 01300-700-0260	
Clerk	11	MO	$2,337			$2,337	$25,711	HCCD 01300-700-0010	
Project Manager	11	MO	$11,876			$11,876	$130,631	HCCD 01300-700-0200	
Field Engineer	11	MO	$7,238			$7,238	$79,622	HCCD 01310-700-0120	
Electric	11	MO		$226		$226	$2,486	Engineering Estimate	
Electric Install	1	EA	$548	$1,526	$153	$2,227	$2,227	HCCD 01510-050-0130	
Telephone - 2 lines	22	MO		$113		$113	$2,486	Engineering Estimate	
Portable Toilet - 4	44	MO		$176.28		$176	$7,756	HCCD 01590-400-6410	
Field Office Expenses	11	MO		$157.07		$157	$1,728	HCCD 01520-550-0100	
Water							By ODEQ		
1a Subtotal							*$377,000*		

1b - Construction Operations Plan, Quality Control Plan, Site Safety Plan, and Other Submittals									
Plans		LS					$50,000	Engineering Estimate	
1b Subtotal							*$50,000*		
1c - Pre-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1c Subtotal							*$9,200*		
1d - Surveying During Construction									
HCCD Crew A-7, 2-man	130	DAY	$914.54	$67.24	$0.41	$982.19	$128,000	HCCD Crews	
1d Subtotal							*$128,000*		
1e - Post-Construction Surveying									
HCCD Crew A-7, 3-man	3	DAY	$1,488.74	$67.24		$1,556	$4,668	HCCD Crews	
HCCD Crew A-7, 2-man off.	5	DAY	$914.54		$0.41	$914.95	$4,575	HCCD Crews	
1e Subtotal							*$9,200*		
1f - Quality Control During Construction									
Quality Control		LS					$40,000	Engineering Estimate	
1f Subtotal							*$40,000*		
PAY ITEM 1 TOTAL							**$613,400**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).

Cost Worksheet

Conceptual Design (50%)

Pay Item Number: 2
Description: Removal, On-Site Consolidation and Stabilization, and Off-Site Disposal

Project: McCormick & Baxter - Impermeable Cover
Location: Portland, Oregon
Base Year: 2004

Work Statement and Assumptions:

Work Statement: This element includes Clearing (Item 2a); Relocating Large Woody Debris (Item 2b); Utility Abandonment (Item 2c); Structure Demolition (Item 2d); Monitoring Well Abandonment (Item 2e); RCRA Hazardous Waste Handling, Transportation, and Off-Site Disposal (Item 2f); Non-Hazardous Waste Handling, Transportation, and Off-Site Disposal; and Erosion and Sedimentation Control (Item 2h).

Assumptions:

1. Assume 50% of the upland portion of the site will require selective clearing: 17.1 acres
2. Assume 10 tons of large woody debris will require consolidation and removal.
3. Utility abandonment assumptions:
   *Water: 1365 ft. of waterline to be abandoned with grout; 10 hydrants removed
   *Electric: 500 ft. of electric lines removed; 5 utilty poles removed
4. Building demolition assumptions:
   *Shop building: 45 ft. x 60 ft. x 20 ft = 54,000 cf; 2700 sf foundation, 6" thick
   *Assume soil beneath 1/2 of building contaminated to 4' bgs. Resulting soil volume = 200 cy = 240 tons (assuming 1.2 tons/cy)
   *Connex box: 3,200 cf
   *Tank: assume 5,000 gallons
5. Monitoring well abandonment: assume 20 monitoring wells to be abandoned; 40 feet deep each or 800 vertical linear feet (vlf)
6. RCRA haz. waste: assume 240 tons soil (per #4, above) plus 10 tons misc.
7. Non-haz. waste: assume 500 tons
8. Erosion control assumptions:
   *Silt fence around site perimeter: 5,561 linear feet
   *Straw bales: 500 linear feet

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
2a - Clearing									
Selective clearing, with dozer and brush rake, light	17	ACRE	$83	$98		$180	$3,100	HCCD 02230-200-0010	
2a Subtotal							*$3,100*		
2b - Relocating Large Woody Debris									
HCCD Crew B-10U	1	DAY	$649	$762.52		$1,412	$1,412	HCCD Crews	
HCCD Crew B-13C	1	DAY	$2,728	$1,810.26		$4,539	$4,539	HCCD Crews	

2b Subtotal							*$5,950*		
2c - Utility Abandonment									
Abandon water piping	1,365	LF	$2.13	$0.47		$3	$3,556	HCCD-02220-875-2900	
Fire hydrant removal	10	EA	$445	$109.05		$554	$5,545	HCCD 02220-240-0900	
Abandon electric lines	500	LF	$2.18	$0.45		$2.63	$1,314	Engineering Estimate	
Remove utility poles	5	EA				$500	$2,500	Engineering Estimate	
2c Subtotal							*$12,900*		
2d - Structure Demolition									
Steel building demolition, shop	54,000	CF	$0.16	$0.14		$0.29	$15,779	HCCD 02220-110-0500	
Demo 6" conc. slab on grade	2,700	SF	$4.91	$0.49		$5.39	$14,560	HCCD 02220-130-0420	
Excavate contaminated soil	200	CY	$0.98	$1.10		$2.09	$417	HCCD 02315-424-0260	
Steel building demolition, conex box	3,200	CF	$0.16	$0.14		$0.29	$935	HCCD 02220-110-0500	
Remove tank to 5,000 gal	1	EA	$1,039.79	$97.50		$1,137	$1,137	ERCD 16-01-9033	
Misc. item removal		JOB					$5,000	Engineering Estimate	
2d Subtotal							*$37,800*		
2e - Monitoring Well Abandonment									
Well abandonment	800	VLF				$42.22	$33,800	Remtech unit price	
2e Subtotal							*$33,800*		
2f - RCRA Hazardous Waste Handling, Transportation, and Off-Site Disposal									
Contaminated soil beneath shop building	240	TONS				$600	$144,000	Remtech unit price	
Misc. waste	10	TONS				$601	$6,010	Remtech unit price	
2f Subtotal							*$150,000*		
2g - Non-Hazardous Waste Handling, Transportation, and Off-Site Disposal									
Non-haz waste	500	TONS				$64.00	$32,000	Remtech unit price	
2g Subtotal							*$32,000*		
2h - Erosion and Sedimentation Control									
Silt Fence, polypropylene	5,561	LF	$0.45		$0.34	$0.79	$4,401	HCCD 02370-700-1000	
Hay Bales, Staked	500	LF	$0.44	$0.06	$2.35	$2.84	$1,421	HCCD 02370-700-1250	
2h Subtotal							*$5,800*		
PAY ITEM 2 TOTAL							**$281,400**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).
R.S. Means, 2004, Environmental Remediation Cost Data 10th Annual Edition (ERCD).

Cost Worksheet

Conceptual Design (50%)

Pay Item Number:	3
Description:	Earthwork, Geosynthetics, and Paving
Project:	McCormick & Baxter - Impermeable Cover
Location:	Portland, Oregon
Base Year:	2004

Work Statement and Assumptions:

Work Statement: This element includes the following work items: Site Smoothing (Item 3a); Contour Development (Item 3b); Geosynthetic Clay Liner Installation (Item 3c); Cap Fill (Item 3d); Vegetation (Item 3e); and Asphalt Paving (Item 3f).

Assumptions:

1. Area within barrier wall and above greenway limit (14.94 acres) to be covered with a RCRA cap = 14.94 acres = 650,800 sf = 72,300 sy. Area outside barrier wall (less paved entrance) covered with 2 ft. soil cap = 18.19 acres = 792,350 sf = 88,040 sy.
2. RCRA cap profile, top to bottom: 12" topsoil; geotextile filter fabric; 6" gravel/biotic layer; 6" sand/gravel drainage layer; geonet composite (drainage layer); flexible membrane liner; geosynthetic clay liner; 6" sand leveling layer; subgrade (contoured for 2% drainage).
3. Assume site smoothing/grading over entire site: 34.01 acres = 164,600 sy.
4. Contour development/subrade preparation below RCRA cap: Assume 2% grade required for adequate drainage. To achieve 2% grade, assume two parallel ridges 1,250 feet long each running NW to SE within the barrier wall area. Assume an average barrier wall width (from bank greenway limit to NE side of wall) of 500 feet. Position ridges at 1/4 and 3/4 of the wall width with a valley positioned at 1/2 the width. Using an average slope length of 125 feet (1/4 barrier wall area width), the calculated ridge height is 2.5 feet to achieve 2% slope. The resulting volume of fill to build ridges = 1/2 (length x width x heighth) x 2 ridges = 1/2 (1250 feet x 250 feet x 2.5 feet) x 2 = 781,250 cubic feet = 28,935 cubic yards = 31,830 tons (assuming 1.1 tons/cubic yard). Assume St. Helens soil will be used for this contour development.
5. Assume average haul distance from stockpile to barrier wall area for contour development = 1/4 mile roundtrip.
6. Assume a 2' deep perimeter trench will be excavated at the site permiter along the BNRR, UPRR, and Triangle Park property lines. Resulting trench length = 4680 ft. Assuming 3:1 slope to trench bottom. Resulting excavation volume = 1040 cy. Assume material is spread within site (prior to demarcation layer placement).
7. Assume 2 feet soil cap fill depth over remainder of site outside barrier wall, less asphalt entrance area (0.97 acres). Soil cap area = 18.19 acres - 0.97 acres = 17.22 acres = 83,345 sy. Cap volume = 55,560 cy = 61,115 tons (assuming 1.1 tons/cy).
8. Stormwater collection/conveyance system: Assume stormwater from RCRA cap drainage layer is collected in 4" perforated piping along toes of each 2% slope. Total perforated piping length = 4525 feet (per conceptual plan), assuming 3 lines of perforated piping. Assume perforated piping then drains to 6" solid wall conveyance piping, which discharges into the existing storm sewer line located near the southern property line. Total solid wall conveyance piping length = 595 feet. Assume manholes are installed on 300 feet centers along piping lines. Total number of manholes = 17.
9. Assume entire site will be vegetated with native upper riparian vegetation (seeding), per City of Portland.
10. Assume site entrance asphalt area will be capped and repaved. Total paved area = 1.08 acres = 47,050 sf = 5,230 sy. [Note, a portion of the paved area (0.11 acres) is outside of the property boundary. Assume this area will also be repaved]. The following layers will be placed to achieve a 2' thick cap over this area: 1" asphalt top course over 3" asphalt binder course over 6" crushed rock over 14" select granular fill.

Description	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	Reference	Notes
3a - Site Smoothing									
Grade subgrade	164,600	SY	$0.24	$0.14		$0.38	$62,400	HCCD 02310-100-0200	
3a Subtotal							*$62,400*		
3b - Contour Development (within barrier wall)									
Soil fill material (St. Helens), stockpiled on-site	31,830	TONS				$10.00	$318,300	Remtech Unit Price	
Load soil from stockpile onto dumptruck; front end loader, 5 cy bucket	28,935	CY	$0.24	$0.29		$0.54	$15,550	HCCD 02315-210-7080	
Haul soil, 12 cy dump truck, 1/4 mile round trip	28,935	CY	$1.27	$1.88		$3.15	$91,030	HCCD 02315-490-0310	
Spread dumped material; by dozer, no compaction	28,935	CY	$0.64	$0.97		$1.62	$46,747	HCCD 02315-520-0020	
Rough grading, 14G, 1 pass	72,300	SY	$0.59	$0.69		$1.28	$92,600	ERCD 17-03-0103	
3b Subtotal							*$564,200*		
3c - Geosynthetic Clay Liner									
GCL material	650,800	SF			$0.43	$0.43	$279,500	ERCD 33-08-0520	
Install GCL	650,800	SF	$0.16	$0.08		$0.24	$153,400	ERCD 33-08-0508	
3c Subtotal							*$432,900*		
3d - Flexible Membrane Liner									
Install 40 mil HDPE Liner	650,800	SF	$1.57	$0.18	$0.34	$2.09	$1,357,400	ERCD 33-08-0571	
3d Subtotal							*$1,357,400*		
3e - Geonet Composite									
Install drainage netting	650,800	SF	$0.09	$0.01	$0.47	$0.57	$372,800	ERCD 33-08-0513	
3e Subtotal							*$372,800*		
3f - 6" Sand Drainage Layer									
Select granular fill placed with front end loader (6" deep)	12,050	CY	$0.38	$0.19	$8.48	$9.05	$109,100	HCCD 02315-210-5070	
Rough grading, 14G, 1 pass	72,300	SY	$0.59	$0.69		$1.28	$92,600	ERCD 17-03-0103	
3f Subtotal							*$201,700*		

3g - 6" Biotic Layer									
Select granular fill placed with front end loader (6" deep)	12,050	CY	$0.38	$0.19	$8.48	$9.05	$109,100	HCCD 02315-210-5070	
Rough grading, 14G, 1 pass	72,300	SY	$0.59	$0.69		$1.28	$92,600	ERCD 17-03-0103	
3g Subtotal							*$201,700*		
3h - Geotextile Filter									
Install 8 oz geotextile filter fabric	72,300	SY	$0.75	$0.02	$0.82	$1.60	$115,400	ERCD 33-08-05232	
3h Subtotal							*$115,400*		
3i - 12" Topsoil (within barrier wall)									
Soil fill material (St. Helens), stockpiled on-site	26,500	TONS				$10.00	$265,000	Remtech Unit Price	
Load soil from stockpile onto dumptruck; front end loader, 5 cy bucket	24,100	CY	$0.24	$0.29		$0.54	$12,951	HCCD 02315-210-7080	
Haul soil, 12 cy dump truck, 1/4 mile round trip	24,100	CY	$1.27	$1.88		$3.15	$75,819	HCCD 02315-490-0310	
Spread dumped material; by dozer, no compaction	24,100	CY	$0.64	$0.97		$1.62	$38,936	HCCD 02315-520-0020	
3i Subtotal							*$392,700*		
3j - Demarcation Fabric Installation (outside barrier wall)									
Install HDPE Fabric	83,345	SY				$0.62	$51,700	Remtech Unit Price	
3j Subtotal							*$51,700*		
3k - 2' Soil Cap (outside barrier wall)									
Soil fill material (St. Helens), stockpiled on-site	61,115	TONS				$10.00	$611,150	Remtech Unit Price	
Load soil from stockpile onto dumptruck; front end loader, 5 cy bucket	55,560	CY	$0.24	$0.29		$0.54	$29,858	HCCD 02315-210-7080	
Haul soil, 12 cy dump truck, 1/4 mile round trip	55,560	CY	$1.27	$1.88		$3.15	$174,792	HCCD 02315-490-0310	
Spread dumped material; by dozer, no compaction	55,560	CY	$0.64	$0.97		$1.62	$89,763	HCCD 02315-520-0020	
3k Subtotal							*$905,600*		

3l - Perimeter Trench Excavation									
Trench Excavating, 1ft. to 4ft. deep; hydraulic backhoe	1,040	CY	$3.31	$1.92		$5.23	$5,400	HCCD 02315-610-0062	
Spread fill with loader, 300' haul	1,041	CY	$1.08	$1.44		$2.51	$2,600	HCCD 02315-520-0170	
3l Subtotal							*$8,000*		
3m - Stormwater Collection and Conveyance									
4" diameter perforated PVC piping	4,525	LF	$6.25	$2.46	$1.83	$10.54	$47,696	ERCD 33-26-0901	
6" diameter HDPE piping	595	LF	$5.12	$2.99	$2.11	$10.22	$6,083	HCCD 02510-760-0200	
Manholes, precast concrete, 4' ID, 4' deep	17	EA	$386.28	$508.50	$65.54	$960.32	$16,300	HCCD 02630-400-1110	
3m Subtotal							*$70,100*		
3n - Vegetation									
Seeding	33.13	ACRE	$84.66		$1,627.81	$1,712.47	$56,734	City of Portland	
Fertilizer	33.13	ACRE				$500.00	$16,565	Ecolotree	
3n Subtotal							*$73,300*		
3o - Asphalt Paving									
Select granular fill placed with front end loader (14" deep)	2,034	CY	$0.38	$0.19	$8.48	$9.05	$18,406	HCCD 02315-210-5070	
Crushed 1-1/2" stone base, compacted to 6" deep	5,230	SY	$0.63	$0.58	$6.72	$7.93	$41,454	HCCD 02740-200-0302	
Asphalt concrete pavement, lots; 3" thick binder course, 1" thick topping	47,050	SF	$0.16	$0.12	$0.64	$0.93	$43,521	HCCD 02740-315-0500	
3o Subtotal							*$103,400*		
PAY ITEM 3 TOTAL							**$4,913,300**		

References:

R.S. Means, 2004, Heavy Construction Cost Data 18th Annual Edition (HCCD).
R.S. Means, 2004, Environmental Remediation Cost Data 10th Annual Edition (ERCD).